

Final Report

**Bioaccumulation of Selenium by Brine Shrimp
(*Artemia franciscana*) and Indigenous Algae
(*Dunaliella viridis*) in Great Salt Lake Waters**

Prepared for:
Kennecott Utah Copper, Inc

January 2007
University of Wyoming
Laramie, WY

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EXECUTIVE SUMMARY

This study determined the accumulation of selenium (sodium selenate, SeO_4 , Se(+VI); sodium selenite, SeO_3 , Se(+IV)) by Great Salt Lake algae (*Dunaliella viridis*) and brine shrimp (*Artemia franciscana*) in Great Salt Lake water at environmentally relevant concentrations of selenium. Both algae and brine shrimp were exposed via aqueous exposure. Brine shrimp were also exposed to selenium via a dietary pathway. Accumulation was measured as whole tissue accumulation after varied periods of exposure under static renewal conditions. Studies commenced with algae in growth phase or 15 day old shrimp. Because the exposure time necessary to achieve steady state tissue burden was unknown, initial exposure periods were extended in subsequent tests. Moreover, some tests we evaluated whether tissue accumulation differed between two selenate and selenite chemical species. Test concentrations were approximately 2, 10, 27 $\mu\text{g L}^{-1}$ with exploratory evaluation of concentrations as high as 208 $\mu\text{g L}^{-1}$. Algae were exposed to selenate and selenite for 12-60 days, whereas, shrimp were exposed for 10-40 days.

Tissue levels appear to reach an asymptote in concentrations as high as 27 $\mu\text{g L}^{-1}$ in the Great Salt Lake exposure matrix. Algal concentrations were $\leq 3 \text{ mg / kg}$ dry weight. For Se concentrations $\leq 27 \text{ ppb Se}$, shrimp tissue accumulations were always less than a bird dietary threshold of 5 mg / kg dry weight. Dietary exposures of shrimp (with concurrent water exposure) resulted in slightly higher tissue levels than water only exposures. Exposure in the laboratory resulted in levels that are not significantly different than those in brine shrimp collected in full-strength Great Salt Lake waters (Brix et al. 2004). Brine shrimp exposures to Se in water and algae are not related to exposure concentration in the range of 1-11 $\mu\text{g L}^{-1}$. Thus, brine shrimp appear to regulate bioaccumulation of this essential trace nutrient in Great Salt Lake waters if selenium is $\leq 27 \mu\text{g L}^{-1}$ regardless of chemical species. Selenite is taken up more rapidly than selenate. Table E-1 provides a summary of selenium accumulation for the various aqueous and dietary exposures after the maximal exposure period in each bioassay. Accumulations at intermediate exposure periods, as well as the maximal periods, are reported in the Results section.

Table E-1. Summary of Bioaccumulation for Maximal Exposure Period in Bioassays

Test #	Test species	Se species	Exposure pathway	Maximal Duration (d)	Observed Se conc. ($\mu\text{g L}^{-1}$)	Tissue Se (mg kg^{-1} dwt)
1	D. viridis	SeO ₄	aqueous	4	0.0	<0.05 (0.00)
					1.0	<0.05 (0.01)
					10.2	<0.05 (0.002)
					16.3	<0.05 (0.01)
					23.5	0.02 (0.01)
					47.9	0.07 (0.01)
2	A. franciscana	SeO ₄	aqueous	4	0.2 22.6 41.8	0.1 (0.01) 0.1 (0.01) 0.1 (0.02)
3	A. franciscana	SeO ₄	aqueous	10	0.2 23.8 48.2	1.1 (n.a.) 2.5 (1.56) 1.8 (0.35)
4	A. franciscana	SeO ₄	aqueous	4	79.8	4.5 (3.13)
5	D. viridis	SeO ₄	aqueous	20	0.0 2.4 8.6	0.2 (0.16) <0.05 (0.00) 0.2 (0.02)
6	D. viridis	SeO ₄	aqueous	60	0.0 2.4 8.6 21.0	1.0 (0.08) 0.8 (0.23) 1.4 (0.42) 1.8 (0.07)
7	A. franciscana	SeO ₄	dietary & aqueous	40	0.4 2.0 9.1 27.1	4.1 (0.76) 3.2 (1.06) 3.7 (0.50) 4.3 (0.68)
8	D. viridis	SeO ₄	aqueous	1	0.4 1.8 7.6	0.5 (0.24) 0.4 (0.07) 0.5 (0.24)
9	A. franciscana	SeO ₄	aqueous	10	0.4 8.2 206.0	0.9 (0.42) 1.6 (0.15) 10.0 (1.13)
10	A. franciscana	SeO ₄	aqueous	10	0.4 8.8	1.8 (0.65) 1.9 (0.15)
11	D. viridis	SeO ₃	aqueous	12	0.5 2.8 12.2 33.4	0.3 (0.23) 1.9 (0.23) 2.1 (0.06) 3.2 (0.20)
12	A. franciscana	SeO ₃	aqueous	10	0.4 2.4 11.6	1.3 (0.41) 1.4 (0.06) 1.6 (0.25)
13	A. franciscana	SeO ₃	dietary & aqueous	10	0.4 2.5 10.7	2.5 (0.15) 2.9 (0.67) 3.1 (1.49)

Dwt = dry weight.

1. INTRODUCTION

This report summarizes a study evaluating the accumulation of selenium (as sodium selenate and sodium selenite) by *Dunaliella viridis*, an indigenous green alga, and by brine shrimp (*Artemia franciscana*) in undiluted Great Salt Lake water at environmentally relevant concentrations of selenium. The Great Salt Lake is an important staging and breeding area for millions of migratory waterfowl and shorebirds that feed on its abundant brine shrimp (*Artemia franciscana*) (Jehl 1994). Brine shrimp are the largest aquatic predators able to tolerate the high salinities of the lake, which are ~3 to 10 times greater than seawater (Domagalski et al. 1989). Aqueous Se concentrations that have little or no effect on brine shrimp can cause teratogenic effects in the waterfowl and shorebird species that feed on them because the bioavailability of organically bound Se is much greater than Se-inorganic complexes. A conservative dietary threshold for avifauna is 5 mg Se kg⁻¹ dry weight of brine shrimp (Heinz et al. 1989, Skorupa et al. 1996).

Because of its unusual water chemistry, generic water quality criteria do not apply to Great Salt Lake, requiring the development of site-specific criteria for municipal and industrial inputs of Se from the Salt Lake City metropolitan area. Currently, concentrations for Se discharge from Kennecott copper smelting facility are based the relationship shown below (Fig. 1) between *in situ* measures of total waterborne Se and tissue Se in brine shrimp along a channelized outflow from the copper facilities extending into the Great Salt Lake (Brix et al. 2004). From this regression, a site-specific, water quality discharge limit was set at 27 µg Se L⁻¹.

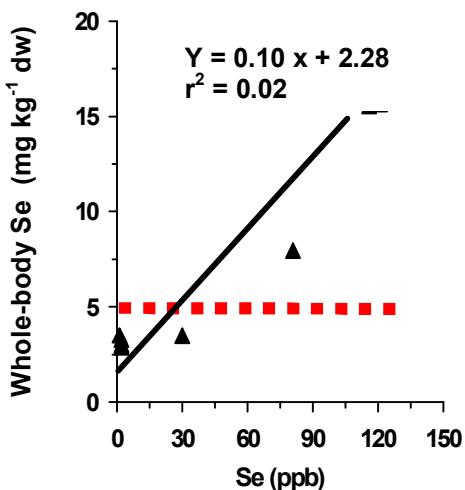


Fig. 1. Relationship Between Aqueous Selenium and Concentrations in Shrimp Collected from the Great Salt Lake (after Brix et al. 2004). Dashed line represents a suggested dietary threshold for avifauna at 5 mg Se kg⁻¹ dry weight of brine shrimp (Heinz et al. 1989, Skorupa et al. 1996).

This study was conducted at Red Buttes Environmental Research Laboratory at the University of Wyoming, Laramie, Wyoming from 1 June 2005 through 31 September 2006. Accumulation was determined from whole organism concentrations after exposure to selenium in static-renewal bioassays. Chronic exposures followed the methods outlined by the United States Environmental Protection Agency (U.S. EPA, 2002). Aqueous selenium analyses were conducted by Kennecott Environmental Laboratory, Magna, Utah with confirmatory analyses by Laboratory and Environmental Testing, Incorporated at Columbia, Missouri. Definitive analyses of aqueous selenium were conducted by Brooks Rand Laboratory, Seattle, Washington. All tissue samples were analyzed by Laboratory and Environmental Testing, Incorporated at Columbia, Missouri.

This report presents methods and results of the study. Section 2 describes the materials (physical system, test matrix and test system) and test methods (culture and testing techniques used to meet the study objectives). Section 3 contains the biological and analytical results and Section 4 presents the study conclusions. Section 5 discusses protocol deviations and their implications. Section 6 contains references, followed by appendices in Section 7 that contain miscellaneous information and the study protocol. Section 8 lists the copious test notes, monitoring observations, and raw data that are provided on disk in a pdf format.

2. METHODS AND MATERIALS

2.1 Test Organisms

2.1.1 Source and Condition of Test Organisms

Brine shrimp cysts were purchased from Argent Chemical laboratories in Redmond, Washington, and were certified to be *Artemia franciscana*, collected from the Great Salt Lake, Utah. Cysts were stored in the dark at 4°C until used for testing.

Cultures of *Dunaliella viridis* were obtained from Gary Belovsky of the University of Notre Dame who had collected them from Great Salt Lake.

2.1.2 Brine Shrimp Cultures

Brine shrimp cysts were purchased from Argent Chemical Laboratories in Redmond, Washington and were certified to be *Artemia franciscana*, collected from the Great Salt Lake, Utah. Cysts were stored in the dark at 4°C until used for testing. Fifteen days prior to test initiation, *Artemia franciscana* cysts were placed in a 1 L Imhoff Cone for overnight hatching at 27°C and 30 g L⁻¹ salinity under moderate aeration. The following day, nauplii were randomly introduced into 20 L culture tanks containing a mixture of artificial brine mix (Instant Ocean™) and deionized water, diluted to 35 g L⁻¹. Shrimp were raised according to conditions in Table 1 in water air-lift raceways (Fig. 7.A.1 in Appendix) to the age of 15 days, after which tests began. Standard glass aquaria fitted with bent sheets of lexan® to form oval raceways. Water in rearing tanks was treated by renewal every 3 days through a water treatment tank. Each water-treatment tank contained 20 L of brine and was fitted with 2 laboratory-grade charcoal water filters for 30-60 gallon tanks (Whisper®).

Table 1. Summary of Rearing Conditions for *Artemia franciscana*

Species	<i>Artemia franciscana</i>
Source	Argent Labs, Redmond, WA
Rearing Tanks	Oval raceways
Aeration and Circulation	Air-water-lifts
Tank Solutions	Diluted commercial hypersaline brine (Instant Ocean®)
Salinity (g/L)	35
Feeding, day 1 to 4	Continuous drip of yeast-cerophyll-trout chow culture (YCT) at ~1 mL min ⁻¹ tank ⁻¹ (U.S. EPA 2000)* 2 scoops freeze-dried rotifers (Brine Shrimp Direct)
Feeding, day 5 to 14	Continuous drip of YCT at ~1 mL min ⁻¹ tank ⁻¹ (U.S. EPA 2002), 100 mL 60 mL Dunaliella viridis (~20 x 10 ⁶ cells mL ⁻¹)
Temperature	25°C
pH	8.5
Light	Fluorescent, growth spectrum, ~100 foot candle intensity
Photoperiod	16 light / 8 dark
Water treatment	Renewal of entire volume through water treatment tank every 3 days Discarding of 0.5 to 1 L of detritus siphoned from tank bottom daily Replenishment with fresh hyposaline brine daily

*Selenium concentration in food sources are listed in Appendix A, Table 6.A.

2.1.3 Algal Cultures

Cultures of *Dunaliella viridis* were obtained from Gary Belovsky of the University of Notre Dame. Algae were cultured in either water from Great Salt Lake or in artificial brine created from a mixture of deionized water and reagent grade compounds purchased from scientific supply companies. Algae were cultured according to conditions in Table 2 in glass carboys under continuous light from lamps mounted above, behind, and at the side of carboys (Fig 7.A.2 in Appendix). Glass carboys were continuously aerated by individual, aquaria air pumps (Whisper®). Tests began when algal cultures were in growth phase.

Table 2. Summary of Culture Conditions for *Dunaliella viridis*

Species	<i>Dunaliella viridis</i>
Source	Gary Belovsky Department of Biological Sciences Galvin, Notre Dame, IN 46556 Phone: 574-631-6552
Rearing Tanks	24 L glass carboys
Rearing Technique	Batch culture (Hoff and Snell 2004)
Tank Solutions	GSL water or synthetic brine (mixed from reagent grade chemicals)
Salinity (g/L)	40
Feeding	Commercial nutrients (Pro-Culture F/2 Algal Formula)
Temperature	25°C
pH	8.5
Light	Fluorescent, growth spectrum; intensity of ~1,000 foot candle
Photoperiod	Continuous light

2.2 Physical System

The physical testing system consisted of 800 mL polypropylene beakers placed in a continuous-flow static bath. Water was warmed in an adjacent tank with a thermostatically controlled heater bar then continuously pumped into the static bath. Beakers were continuously aerated by individual air tubes adjusted to release 100 bubbles per minute. Lighting for the test system consisted of growth-spectrum fluorescent lights adjusted to 100-150 foot candle intensities set on a 16-hour light / 8 hour dark photoperiod. Each concentration and control had 3 replicates. Beakers were covered with lexan sheets to minimize evaporate loss that might alter solute concentrations (Fig. 7.A.2 in Appendix).

2.3 Test Substance

The test substances, reagent grade sodium selenate (Na_2SeO_4 ; CAS # 013410-01-0) and sodium selenite (Na_2SeO_3 ; CAS # 10102-18-8), were received from Sigma-Aldrich Chemical Company, St. Louis, MO. Following receipt at the University of Wyoming in Laramie, Wyoming, the test substance was stored in the dark at room temperature.

2.4 Test Matrix / Control Water

Test matrix and control waters consisted of water collected on 24 July 2005, 15 September 2005, 21 November 2005, 28 March 2006, and 20 June 2006 from the Great Salt Lake. The collection site was approximately 1 mile north of the southern shore in the south arm of the Great Salt Lake, halfway between Antelope and Fremont Islands. Salinity varied between 80 and 120 g L^{-1} , depending on season. Water was collected in leached, 20 gallon HDPE carboys by staff from the Utah Division of Wildlife Resources working with staff from Kennecott Utah Copper, Incorporated. Upon arrival at the University of Wyoming, water was filtered through an extensively pre-rinsed system of in-line cartridge filters (20 and 1 μm Hytrex® filters) then stored at 5°C in leached, 20 gallon HDPE carboys in the dark. Samples of the Great Salt Lake water were analyzed at Red Buttes Environmental Research Laboratory for cations, anions, cadmium, copper, iron, lead, and zinc (Appendix 7.A, Table 7.A.1). Values for metals concentrations are recognized to be biased on the high side due to chloride interference in the Great Salt Lake water.

Waters used in tests encompassed the range in geochemical variability that typifies the GSL. Metal concentrations were below both acute (CMC) and chronic (CCC) criteria for priority pollutants (U.S. EPA 2006) for freshwater or saltwater. Only the sample collected on 9-15-2005 exceeds copper concentrations reported by Domagalski et al. (1990; 7 $\mu\text{g L}^{-1}$) for the South end of the Great Salt Lake. Salinity ranged from 80 to 120 g L^{-1} , and was dominated by sodium and chloride ions. Dissolved organic carbon (DOC) concentration in the water ranged from 29 to 48 mg L^{-1} , which is characteristic of the Great Salt Lake (Domagalski et al. 1990).

2.5 Water Quality Parameters

Water quality parameters (pH, temperature, and salinity) in each test chamber and water temperature in the physical system were measured at test initiation and daily. Dissolved oxygen was measured at test initiation and when exposure solutions were renewed, meaning daily for shrimp and once every 4 days for the algae. Test solution pH was measured using pH indicator strips (Whatman) because pH meters are unreliable at the salinities of this study. Dissolved oxygen was measured using a Hach Co. Dissolved Oxygen Test Kit, model OX-2P. Salinity was measured using a Fisherbrand temperature compensated refractometer. All instruments were calibrated the day of use.

2.6 Test Methods

The methods in this study follow the protocols outlined by the United States Environmental Protection Agency for static renewal tests with brine shrimp and algae (U.S. EPA 2000, 2002). General test conditions are described in Table 3. Conditions for individual tests follow in Table 4.

2.6.1 Test Concentrations and Test Material Handling

A stock solution of selenium was prepared by adding 10 g of reagent grade sodium selenate to 1 L of deionized water, providing a 4.18 g L^{-1} selenium stock solution. The stock solution was held in the dark at ambient temperature. Selenium solutions for tests were diluted to the appropriate concentrations 48 hours prior to test initiation. 24 hours after dilution at 24 h prior to test initiation, labeled test beakers were preconditioned by filling them with 400 mL of the appropriate test solution and allowing 24 hours for any loss of selenium by adhesion to inside surfaces to take place. Preconditioning solutions were discarded immediately prior to introduction of brine shrimp into the test beakers.

Table 3. General Test Conditions

Test title:	Bioaccumulation of Selenium by Brine Shrimp (<i>Artemia franciscana</i>) and an indigenous alga (<i>Dunaliella viridis</i>) in the Great Salt Lake Waters		
Test facility:	Red Buttes Environmental Research Laboratory, 990 Highway 287, Department of Zoology and Physiology, University of Wyoming, Laramie, Wyoming 82070		
Test material:	Selenium as Sodium Selenate (Na ₂ SeO ₄ ; CAS # 013410-01-0) and Sodium Selenite (Na ₂ SeO ₃ ; CAS # 10102-18-8)		
Test species:	<i>Dunaliella viridis</i> (indigenous green alga)	<i>Artemia franciscana</i> (brine shrimp)	<i>Artemia franciscana</i> (brine shrimp)
Life stage:	Growth phase	15 day old adults	15 day old adults
Source of organisms:	Gary Belovsky, Dept of Biological Sciences, Notre Dame University, Notre Dame, Indiana	Argent Labs, Redmond, Washington	Argent Labs, Redmond, Washington
Type of test:	static renewal every 4 days	static renewal daily	
Exposure pathway:	Aqueous	aqueous	dietary
Test duration:	60 days or less (SeO ₄), 12 days or less (SeO ₃)	10 days or less (SeO ₄), 10 days or less (SeO ₃)	40 days or less (SeO ₄), 10 days or less (SeO ₃)
Feeding:	EPA Nutrients (U.S. EPA 2000), 100 µL 2 x day	~10,000 algal cells/animal, 2 x day, <i>D. viridis</i>	Fed <i>D. viridis</i> after its culture in appropriate levels and chemical species of Se for 30 d prior to test ~10,000 algal cells / animal, 2 x day, <i>D. viridis</i>
Number of organisms:	10,000,000 cells mL ⁻¹	~ 1,000 / container	~ 1,000 / container
Replicates:	3	3	3
Exposure matrix:	Synthetic brine* Filtered Great Salt Lake water (1.0 um)	Filtered Great Salt Lake water (1.0 um)	Filtered Great Salt Lake water (1.0 um)
Matrix storage:	≤100 days in leached 1000 gal HDPE	≤100 days in leached 1000 gal HDPE	≤100 days in leached 1000 gal HDPE
Exposure chambers:	800 mL polypropylene beakers	800 mL polypropylene beakers	800 mL polypropylene beakers
Light source:	Broad spectrum fluorescent bulbs	Broad spectrum fluorescent bulbs	Broad spectrum fluorescent bulbs
Photoperiod:	16 hours light ; 8 hours dark	16 hours light ; 8 hours dark	16 hours light ; 8 hours dark
Lt intensity (ft. candle):	100-150	100-150	100-150
Aeration (bubbles/min):	100	100	100
pH:	8.5 ± 1	8.5 ± 1	8.5 ± 1
Salinity (g L⁻¹)	105 ± 25	105 ± 25	105 ± 25
Temp (°C)	25 ± 2	25 ± 2	25 ± 2
Monitoring intervals for pH, salinity, temperature	Test start, Daily	Test start, Daily	Test start, Daily
Dissolved oxygen (DO, mg L⁻¹)	>0.8	>0.8	>0.8
Monitoring for DO	Test start, Every 4 days	Test start, Daily	Test start, Daily
Instrument detection limit (µg Se L⁻¹):	0.2	0.2	0.2
Acceptable coefficient of variation (%)	40	40	40
Effect measured:	Bioaccumulation	Bioaccumulation	Bioaccumulation

*Anion and cation concentrations in synthetic brine were ± 20% that of GSL water.

Table 4. Summary of Individual Test Conditions

	Test #1	Test #2	Test #3	Test #4	Test #5	Test #6	Test #7	Test #8	Test #9	Test #10	Test #11	Test #12	Test #13	
Species	<i>Dunaliella viridis</i>	<i>Artemia franciscana</i>	<i>Artemia franciscana</i>	<i>Artemia franciscana</i>	<i>Dunaliella viridis</i>	<i>Dunaliella viridis</i>	<i>Artemia franciscana</i>	<i>Dunaliella viridis</i>	<i>Artemia franciscana</i>	<i>Dunaliella viridis</i>	<i>Artemia franciscana</i>	<i>Artemia franciscana</i>	<i>Artemia franciscana</i>	
Test start date	9-19-05	9-30-05	10-13-05	10-20-05	12-1-05	<i>I-18-06</i>	<i>3-1-06</i>	5-16-06	5-19-06	5-25-06	5-30-06	6-5-06	6-20-06	
Exposure pathway	aqueous	aqueous	aqueous	aqueous	aqueous	aqueous	dietary and aqueous	aqueous	aqueous	aqueous	aqueous	aqueous	dietary and aqueous	
Se concentration ($\mu\text{g L}^{-1}$)^A	0, GSL, 9, 18, 27, 54	GSL, 27, 54	GSL, 27, 54	108	0, GSL, 2, 10	GSL, 2, 10, 27, 54	GSL, 2, 10, 27	GSL, 2, 10	GSL, 8.5, 206	GSL, 8.5	GSL, 2, 10, 27	GSL, 2, 10, 27	GSL, 2, 10, 27	
Exposure durations (d)^B	0, 0.08, 0.17, 0.33 , 1, 2, 3, 4	0, 1, 4	0, 0.17, 2, 6, 8, 10	1, 4	4, 8, 12, 20	45, 60	0, 0.08, 1, 2, 4, 8, 20, 40	1	1, 2, 4, 10	1, 2, 4, 10	0, 4, 8, 12	0, 4, 8, 10	0, 4, 8, 10	
Exposure waters^C	1.0 um filtered Great Salt Lake water	filtered GSL	filtered GSL	filtered GSL	filtered GSL, synthetic brine	filtered GSL	filtered GSL	filtered GSL	unfiltered GSL	filtered GSL	filtered GSL	filtered GSL	filtered GSL	
Analytical intervals for aqueous Se	Test start, solutions <12 h, then daily	Test start, daily	Test start, solutions <12 h, then daily	Test start	Test start, daily	Test start, daily	Test start, daily	Test start, daily	Test start, daily	Test start, daily	Test start, daily	Test start, daily	Test start, daily	
Sodium Se species	Selenate Se (+VI), $\text{Na}_2\text{SeO}_4^{2-}$	Selenate Se (+VI), $\text{Na}_2\text{SeO}_4^{2-}$	Selenate Se (+VI), $\text{Na}_2\text{SeO}_4^{2-}$	Selenate Se (+VI), $\text{Na}_2\text{SeO}_4^{2-}$	Selenite Se (+IV), $\text{Na}_2\text{SeO}_4^{2-}$	Selenite Se (+IV), $\text{Na}_2\text{SeO}_3^{2-}$	Selenite Se (+IV), $\text{Na}_2\text{SeO}_3^{2-}$	Selenite Se (+IV), $\text{Na}_2\text{SeO}_3^{2-}$						
Analytical intervals for pH, salinity, and temperature	Test start, daily	Test start, daily	Test start, daily	Test start, daily	Test start, daily	Test start, daily	Test start, daily	Test start, daily	Test start, daily					
Analytical interval for dissolved oxygen (d)	Test start, daily ^D	Test start, daily	Test start, daily	Test start, daily	Test start, per 4 d	Test start, per 4 d	Test start, daily	Test start, per 4 d	Test start, daily	Test start, per 4 d	Test start, daily	Test start, daily	Test start, daily	
Test objective	Aqueous uptake of Se (+VI)	Aqueous uptake of Se (+VI)	Aqueous uptake of Se (+VI)	Aqueous uptake of Se (+VI)	Varied SO_4^{2-} : 8,000 mg L^{-1} (GSL), 2.5, 25 mg L^{-1} (brine)	Prolonged uptake of aqueous Se (+VI)	Prolonged uptake of dietary and aqueous Se (+VI)	Variation in Se levels between renewals	Aqueous uptake of Se (+VI)	Test uptake of microbially bound Se	Test of selenite (+IV) uptake	Test of selenite (+IV) uptake	Test of selenite (+IV) uptake	Test of selenite (+IV) uptake
Sample codes, initial digits	descriptive	descriptive	100-174	174-184	600-734	1,000-1,029	800-928	1,100-1,132	1301-1379	1400-1455	1500-1598	1600-1694	1700-1767	

^A Zero (0) concentration was the synthetic brine that lacked added Se. The “GSL” concentration is unamended Great Salt Lake water that contained approximately 0.5 $\mu\text{g Se L}^{-1}$ —sometimes denoted as 1 $\mu\text{g L}^{-1}$ on test forms and sample codes.

^B Samples from the durations in bold font were collected and stored at -80°C but not sent for analysis.

^C Anion and cation concentrations in artificial matrix was $\pm 20\%$ that of GSL water.

^D Solutions were renewed daily, unlike all succeeding algal bioassay tests, which were renewed every 4 d.

2.6.2 Introduction of Brine Shrimp into Physical System

Fifteen days prior to test initiation, *Artemia franciscana* were hatched and reared as described above in sections 2.1.1 and 2.1.2. At the onset of each test, approximately 2,000 adult brine shrimp were randomly introduced into preconditioned beakers then 400 mL of the appropriate test solutions were added. Aeration of beakers at ~100 bubbles per minutes began immediately.

2.6.3 Feeding of Brine Shrimp

Brine shrimp were fed the green algae, *Dunaliella viridis*, a native species collected from GSL by Gary Belovsky from the University of Notre Dame (see section 2.1.3 above). Algae fed to the shrimp during aqueous-only exposures were cultured in artificial brine made at the University of Wyoming from a mixture of reagent grade compounds. For dietary and aqueous exposures of brine shrimp to selenium, algae were cultured in the appropriate selenium species and concentration in GSL water for 30 days prior to the beginning of dietary tests. Although shrimp were not acclimated to the increased salinity in tests, we did not observe any salinity related mortality.

2.6.4 Introduction of Algae into the Physical System.

Sufficient algal concentrations with minimal dilution of test waters was achieved by centrifuging 4 L of algae at 4,000 rpm for 5 minutes so that at the initiation of tests cell counts were $> 4.5 \times 10^6$ cells mL^{-1} in 400 mL of test solution.

2.6.5 Feeding of Algae

During tests, algae were provided with 100 μL 2 times per day of the selenium-free nutrient solution recommended by the U.S. EPA (2000). Aeration of solutions at ~100 bubbles per minute began immediately after test initiation to avoid any possible CO_2 limitation on growth during photosynthesis or anoxia during respiration at night.

2.6.6 Solution Renewal in Algal Studies

Algal solutions were renewed every 4 days by passage through an ultra-filtration cartridge (Pellicon®), which concentrated algal cells in approximately 50 mL of old test solution. To avoid carry over, the ultra-filtration system was extensively rinsed prior to the introduction of any test solution. Treatments were sent through the system beginning with control solutions then continuing from the lowest to highest selenium concentrations with cartridge cleaning between each increase in selenium concentration. Cartridges were cleaned after the final test solution in preparation for the next study.

2.6.7 Test Termination and Biologic Sample Collection

Studies terminated after predetermined exposure periods. Upon termination, brine shrimp samples were rinsed 3 times in deionized water and sealed in minimal volumes of water without headspace in Whirlpak® bags. Prior to collection, Whirlpak® bags were rinsed in 18 Mohm water three times. Algae were concentrated by passage through an ultra-filtration cartridge (Pellicon®) until solution volumes were decreased to approximately 10 mL.

2.7 Analytical Verification of Test Concentrations

During initial studies (Tests 1 through 7, Table 4), water samples were analyzed at the Kennecott Environmental Laboratory, Magna, Utah with replicates sent approximately every 10 samples to Laboratory and Environmental Testing, Incorporated (LET), Columbia, Missouri. Fifty mL of “Initial” (aliquots taken directly from test solutions prior to exposure to algae or shrimp) and “final” samples (aliquots collected from solutions in which biota were exposed) were collected during Tests 1, 2, and 8 (Table 4) in acid-washed, high density polyethylene containers. “Final” samples were filtered through 0.45 µm filters (Whatman®) pre-rinsed with 18 Mohm water. Samples sent to Kennecott or LET were preserved with 1% trace metal grade hydrochloric acid. For tests 8 to 13, water samples were analyzed by Brooks Rand Laboratory, Seattle, Washington with a small number of replicates analyzed by LET. 1,000 mL samples sent to Brooks Rand were not preserved per their protocol and collected in high density

polyethylene, pre-cleaned containers, which they provided. In addition to “initial” samples, Brooks Rand analyzed “final” aliquots collected after biotic exposure on the final day of Tests 12 and 13. Because their protocol required 1 L of solution, waters from the 3 replicates for each treatment were combined to send one “final” aliquot to Brooks Rand. All laboratories analyzed samples using hydride generation. The detection limit for the Kennecott Laboratory was $2 \mu\text{g L}^{-1}$, thus, values for control solutions of unamended GSL and synthetic brine waters were unreliable. In those instances, we report values from LET analyses. Method detection limits from the other two laboratories were $0.05 \mu\text{g L}^{-1}$. We report the average and standard deviation of total selenium concentrations from all laboratories.

2.8 Analysis of Biological Data

This section defines the data evaluation procedures used for statistical analysis of accumulation tests. For visual comparison, data are presented in univariate plots. T-tests were performed to test for significant differences between exposure pathways in addition to selenate versus selenite chemical species. Segmented regression analysis (Hockey Stick) was used to characterize the break point beyond which shrimp demonstrated a dose-response relationship according to aqueous concentrations of selenium

3. RESULTS

3.1 Water Quality Parameters

Water quality parameter (water temperature, dissolved oxygen, pH, and salinity) were measured daily in shrimp tests. In algal tests all parameters were measured daily except oxygen, which was measured every 4 d. All water quality parameters were within guidelines specified in the protocol (Table 3). Average conditions in the tests were a temperature of 25°C, dissolved oxygen was 2.6 mg L⁻¹, pH was 8.5, and salinity was 105.

Table 5. Water Quality During Bioaccumulation Tests

Water Quality Parameter	Mean	Range	Protocol Guidelines
Water Temperature (°C)	25	21 - 27	25 ± 2
Dissolved Oxygen (mg L ⁻¹)	2.6	0.8 – 5.6	>0.8
pH	8.4	8.2 – 9.0	8.5 ± 1
Salinity (g L ⁻¹)	115	80 - 135	105 ± 25

3.2 Test Material Concentrations

To verify selenium test concentrations in the test chambers, samples from each concentration were collected. Selenium concentrations in Table 6 are the averages of solutions analyzed by the specified analytical laboratories. Aside from the unamended GSL water (designated as nominal selenium concentration = 0.5), coefficients of variation for test concentrations ranged from 1% to 40%, which were within the test acceptability criteria of ≤ 40%. One exception was the highest concentration in Test 11, which had a coefficient of variation of 50% because of one very low value in a replicate that could not be rejected. Regarding unamended GSL water, coefficients of variation ranged from 0% to 141%, but absolute differences between expected and average values were <0.5 µg L⁻¹.

3.2.1 Deviation from Protocol

The detection limit for Kennecott Environmental Laboratory was 2 µg Se L⁻¹. Because of this high detection limit, reported concentrations for unamended Great Salt Lake water were as high as 6µg L⁻¹ for solutions that LET reported 0.5 µg L⁻¹. Thus, we rejected values for low selenium concentrations reported by Kennecott if their reported values were >±40% for samples

aside from unamended Great Salt Lake water. In unamended samples, observed values <±150% were accepted. An example of differences between laboratories is shown in Appendix G.

Table 6. Test Material Concentrations

Analytical Laboratory ^a	Test #	Nominal Se ($\mu\text{g L}^{-1}$)	Mean Observed Se ($\mu\text{g L}^{-1}$)	SD	CV (%)
LET, KUCC	1	0	0.0	0.0	n.a.
		0.5	1.0	1.4	141
		9	10.2	1.3	13
		18	16.3	4.4	27
		27	23.5	5.6	24
		54	47.9	5.3	11
LET, KUCC	2	0.5	0.2	0.2	122
		27	22.6	7.8	34
		54	41.8	6.7	16
LET, KUCC	3 and 4	0.5	0.2	0.2	122
		27	23.8	0.4	2
		54	48.2	2.4	5
		108	79.8	11.2	14
LET, KUCC	5	2	2.4	0.9	39
		10	8.6	2.6	30
		2	2.4	0.9	39
		10	8.6	2.6	30
LET, KUCC	6	0.5	0.0	n.a. ^c	n.a.
		2	2.4	0.9	40
		10	8.6	2.6	30
		27	21.0	n.a. ^d	n.a.
LET, KUCC	7	0.5	0.4	0.5	125
		2	2.0	0.1	5
		10	9.1	2.2	24
		27	27.1	2.3	8
LET	8 ^e	0.5	0.7	n.a.	n.a.
		0.5	0.0	n.a.	n.a.
		2.0	1.7	n.a.	n.a.
		2.0	1.9	n.a.	n.a.
		10.0	7.5	n.a.	n.a.
		10.0	7.6	n.a.	n.a.
BR	9	0.5	0.4	0.0	0
		100	8.2	0.1	2
		1000	206.0	1.4	1
LET	10	0.5	0.4	0.0	0
		100	8.8	0.6	7

Table 6. Test Material Concentrations (Concl.)

Analytical Laboratory ^a	Test #	Nominal Se ($\mu\text{g L}^{-1}$)	Mean Observed Se ($\mu\text{g L}^{-1}$)	SD	CV (%)
BR	11	0.5	0.5	0.1	28
		2	2.7	0.4	16
		10	12.2	0.6	5
		27	25.8	13.0	50
BR	12	0.5	0.4	0.0	0
		2	2.4	0.7	28
		10	11.6	2.5	22
BR	13	0.5	0.4	0.02	5
		2	2.5	0.2	9
		10	10.7	0.7	7

3.3 Biological Results

3.3.1 Initial Shrimp Accumulation of Selenium Via Aqueous Exposure

During the first studies of aqueous exposure of selenate to brine shrimp, shrimp entered the test with very low body burdens of selenium (Fig. 2, Tables 7 and 8). Their condition was not consistent with concentrations of this essential nutrient reported for shrimp collected under natural conditions in Great Salt Lake. Thus, we repeated those tests. Ultimately, selenium accumulation by shrimp for exposure periods longer than 6 days and aqueous selenium concentrations less than $45 \mu\text{g L}^{-1}$ did not differ significantly from the results of Tests 9 and 10 (Figure 4).

Fig. 2. Shrimp Accumulation of Aqueous Selenium. Tests were conducted in Great Salt Lake water amended with selenate (Tests 2, 3, and 4). Salinities ranged from $110 - 125 \text{ g L}^{-1}$.

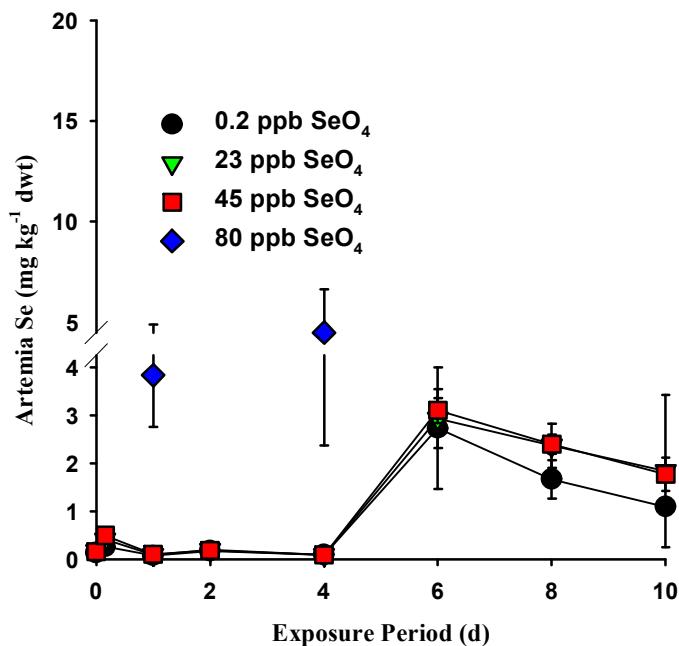


Table 7. Shrimp Accumulation of Aqueous Selenate (Test 2 results). Test duration was 4 days.

Test 2, Artemia, Aqueous SeO ₄				
Observed SeO ₄ ($\mu\text{g L}^{-1}$)	Nominal Se ($\mu\text{g L}^{-1}$)	Exp Time (d)	Mean Se ($\mu\text{g g}^{-1}$ dwt)	SD Se ($\mu\text{g g}^{-1}$ dwt)
0.4	0.5	0	0.14	0.06
0.4	0.5	1	0.08	0.04
0.4	0.5	4	0.10	0.01
23.1	27	0	0.18	0.07
23.1	27	1	0.10	0.00
23.1	27	4	0.09	0.01
44.5	54	0	0.16	0.07
44.5	54	1	0.11	0.06
44.5	54	4	0.09	0.02

Table 8. Shrimp Accumulation of Aqueous Selenate (Test 3 and 4 results). Test duration was 10 days.

Table 8. Shrimp Accumulation of Aqueous Selenate (Test 3 and 4 results).				
Test duration was 10 days.				
Tests 3 & 4, Artemia, Aqueous SeO ₄				
Observed SeO ₄ ($\mu\text{g L}^{-1}$)	Nominal Se ($\mu\text{g L}^{-1}$)	Exp Time (d)	Mean Se ($\mu\text{g g}^{-1}$ dwt)	SD Se ($\mu\text{g g}^{-1}$ dwt)
0.4	0.5	0	0.27	0.11
0.4	0.5	0.17	0.27	0.04
0.4	0.5	2	0.18	0.07
0.4	0.5	6	2.73	1.27
0.4	0.5	8	1.67	0.40
0.4	0.5	10	1.10	0.00*
23.1	27	0.17	0.41	0.06
23.1	27	2	0.20	0.06
23.1	27	6	2.93	0.61
23.1	27	8	2.37	0.46
23.1	27	10	2.50	1.56
44.5	54	0.17	0.50	0.08
44.5	54	2	0.19	0.03
44.5	54	6	3.10	0.26
44.5	54	8	2.40	0.20
44.5	54	10	1.77	0.35
84.0	108	1	3.83	1.07
84.0	108	4	4.50	3.13

*Rejected two replicates for this treatment because of low tissue mass.

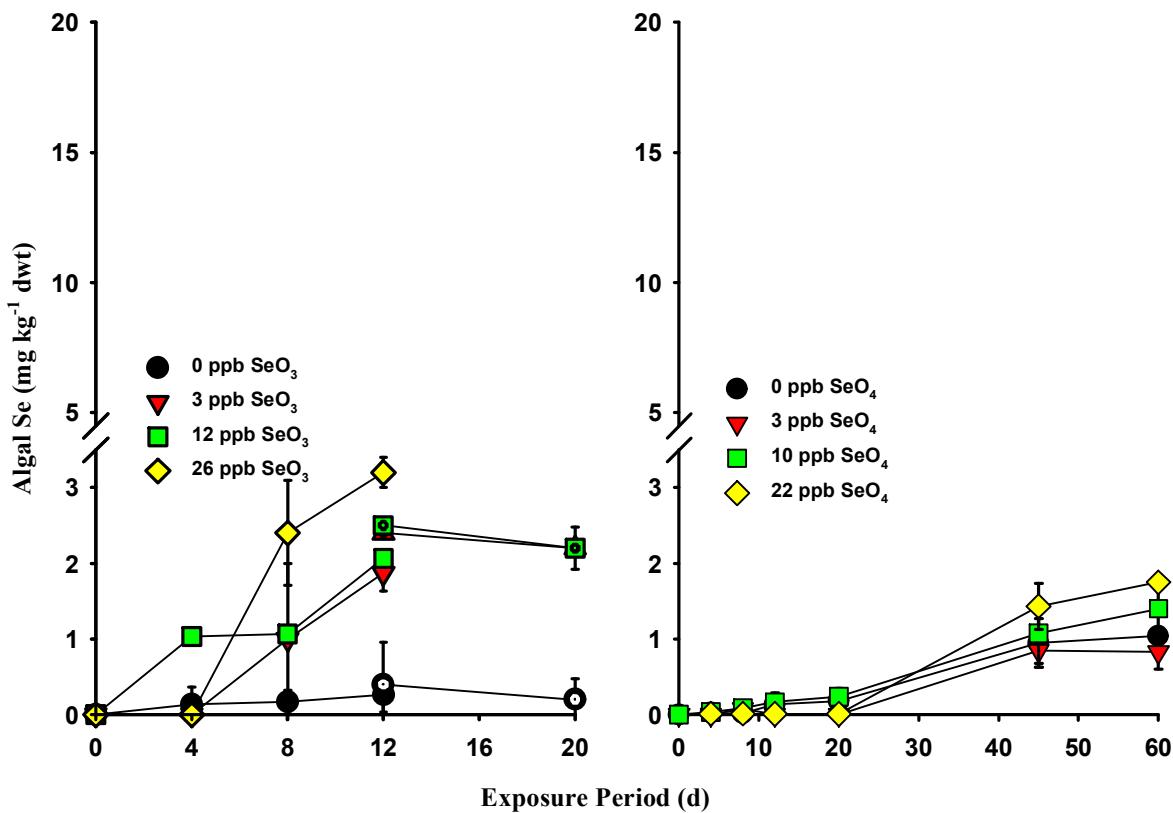


Fig. 3. Algal Uptake of Selenite Versus Selenate. Tests were conducted in Great Salt Lake water (salinity range $105 - 130 \text{ g L}^{-1}$) amended with selenite (Test 11 plus algal culture data, left panel) and selenate (Tests 1, 5, and 6, right panel). Symbols with cross-hatch show tissue accumulation by algae cultured in the presence of selenite (culture salinity = 35 g L^{-1}). Such algae were later fed to brine shrimp in Test 13 (Fig. 5).

3.3.2 Algal Accumulation of Selenium

Selenium accumulations were analyzed in algae and shrimp tissue after extended periods of exposure to 2 species of selenium: selenate and selenite. Comparing algal uptake of the two species of selenium. The results of Test 11 and concurrent algal cultures versus combined results from Tests 1, 5, and 6 indicate that selenite is accumulated more rapidly and to a slightly greater concentration than selenate (Fig. 3, Tables 9, 10, 11, 12, and 13).

Table 9. Controlled Laboratory Experiment: Algal Accumulation of *Selenite*.

Test 11, Dunaliella SeO ₃ , Laboratory Experiment				
Observed SeO ₃ ($\mu\text{g L}^{-1}$)	Nominal Se ($\mu\text{g L}^{-1}$)	Exp Time (d)	Mean Se ($\mu\text{g g}^{-1}$ dwt)	SD Se ($\mu\text{g g}^{-1}$ dwt)
0.5	0.5	0	0.000	0.000
0.5	0.5	4	0.133	0.231
0.5	0.5	8	0.167	0.153
0.5	0.5	12	0.267	0.231
2.8	2	4	*	
2.8	2	8	1.000	1.000
2.8	2	12	1.867	0.231
12.2	10	4	1.033	0.058
12.2	10	8	1.067	0.058
12.2	10	12	2.067	0.058
33.4	27	4	*	
33.4	27	8	2.400	0.693
33.4	27	12	3.200	0.200

*Reject, masses low & values $>8 \mu\text{g g}^{-1}$

Table 10. Algal Culture: Algal Accumulation of *Selenite*.

Test 11, Dunaliella Culture SeO ₃ Uptake				
Observed SeO ₃ ($\mu\text{g L}^{-1}$)	Nominal Se ($\mu\text{g L}^{-1}$)	Exp Time (d)	Mean Se ($\mu\text{g g}^{-1}$ dwt)	SD Se ($\mu\text{g g}^{-1}$ dwt)
0.5	0.5	0	0.000	0.000
0.5	0.5	12	0.400	0.566
0.5	0.5	20	0.200	0.283
2.8	2	12	2.350	0.071
2.8	10	20	2.200	0.000
12.2	2	12	2.500	0.000
12.2	10	20	2.200	0.283

Table 11. Controlled Laboratory Experiment: Algal Accumulation of Selenate (Test 1 results).

Test 1, Dunaliella SeO ₄				
Observed SeO ₄ ($\mu\text{g L}^{-1}$)	Nominal Se ($\mu\text{g L}^{-1}$)	Exp Time (d)	Mean Se ($\mu\text{g g}^{-1}$ dwt)	SD Se ($\mu\text{g g}^{-1}$ dwt)
0.0	0.0	0	0.00	0.00
0.4	0.5	0	0.00	0.00
0.4	0.5	1	0.00	0.00
0.4	0.5	2	0.00	0.00
0.4	0.5	4	0.00	0.00
9.3	9	0	0.01	0.006
9.3	9	0.17	0.01	0.009
9.3	9	1	0.01	0.003
9.3	9	2	0.01	0.007
9.3	9	4	0.01	0.008
16.6	18	0	0.001	0.001
16.6	18	0.17	0.000	0.001
16.6	18	1	0.001	0.001
16.6	18	2	0.003	0.003
16.6	18	4	0.007	0.002
23.5	27	0	0.005	0.007
23.5	27	0.17	0.014	0.013
23.5	27	1	0.015	0.013
23.5	27	2	0.039	0.008
23.5	27	4	0.022	0.008
44.5	54	0	0.001	0.002
44.5	54	0.17	0.000	0.000
44.5	54	1	0.000	0.000
44.5	54	2	0.020	0.006
44.5	54	4	0.068	0.007

Table 12. Controlled Laboratory Experiment: Algal Accumulation of Selenate (Test 5 results).

Test 5, Dunaliella SeO ₄		SO ₄ ²⁻ (mg L ⁻¹)	Exp Time (d)	Mean Se ($\mu\text{g g}^{-1}$ dwt)	SD Se ($\mu\text{g g}^{-1}$ dwt)
Observed SeO ₄ ($\mu\text{g L}^{-1}$)	Nominal Se ($\mu\text{g L}^{-1}$)				
2.4	2	2.5	4	0.00	0.00
2.4	2	2.5	8	0.00	0.00
2.4	2	2.5	12	0.00	0.00
2.4	2	2.5	20	0.00	0.00
8.6	10	2.5	4	0.08	0.01
8.6	10	2.5	8	0.03	0.05
8.6	10	2.5	12	0.00	0.00
8.6	10	2.5	20	0.00	0.00
8.6	10	25	4	0.03	0.06
8.6	10	25	8	0.03	0.06
8.6	10	25	12	0.17	0.06
8.6	10	25	20	0.00	0.00
0.0	0.5	8000	0	0.00	0.00
0.0	0.5	8000	4	0.02	0.04
0.0	0.5	8000	8	0.02	0.03
0.0	0.5	8000	12	0.13	0.15
0.0	0.5	8000	20	0.18	0.16
2.4	2	8000	4	0.00	0.00
2.4	2	8000	8	0.07	0.00
2.4	2	8000	12	0.00	0.00
2.4	2	8000	20	0.00	0.00
8.6	10	8000	4	0.03	0.04
8.6	10	8000	8	0.09	0.02
8.6	10	8000	12	0.05	0.07
8.6	10	8000	20	0.22	0.02

Table 13. Controlled Laboratory Experiment: Algal Accumulation of Selenate (Test 6 results).

Test 6, Dunaliella SeO ₄		Exp Time (d)	Mean Se ($\mu\text{g g}^{-1}$ dwt)	SD Se ($\mu\text{g g}^{-1}$ dwt)
Observed SeO ₄ ($\mu\text{g L}^{-1}$)	Nominal Se ($\mu\text{g L}^{-1}$)			
0.7	0.5	45	0.95	0.32
0.7	0.5	60	1.04	0.08
1.7	2	45	0.85	0.22
1.7	2	60	0.83	0.23
7.6	10	45	1.08	0.40
7.6	10	60	1.40	0.42
21.0	27	45	1.43	0.31
21.0	27	60	1.75	0.07

3.3.3 Shrimp Accumulation of Selenium Via Aqueous Exposure

In contrast to algal accumulation, the results of Test 12 versus Tests 9 and 10 (data combined) indicate that selenite uptake and accumulation by shrimp exposed to aqueous selenium did not differ from that of selenate (Fig. 4, Tables 14, 15, and 16). Because accumulation of selenium was not significantly different in filtered versus unfiltered treatments, data in Tests 9 and 10 were combined in the right panel of Figure 4.

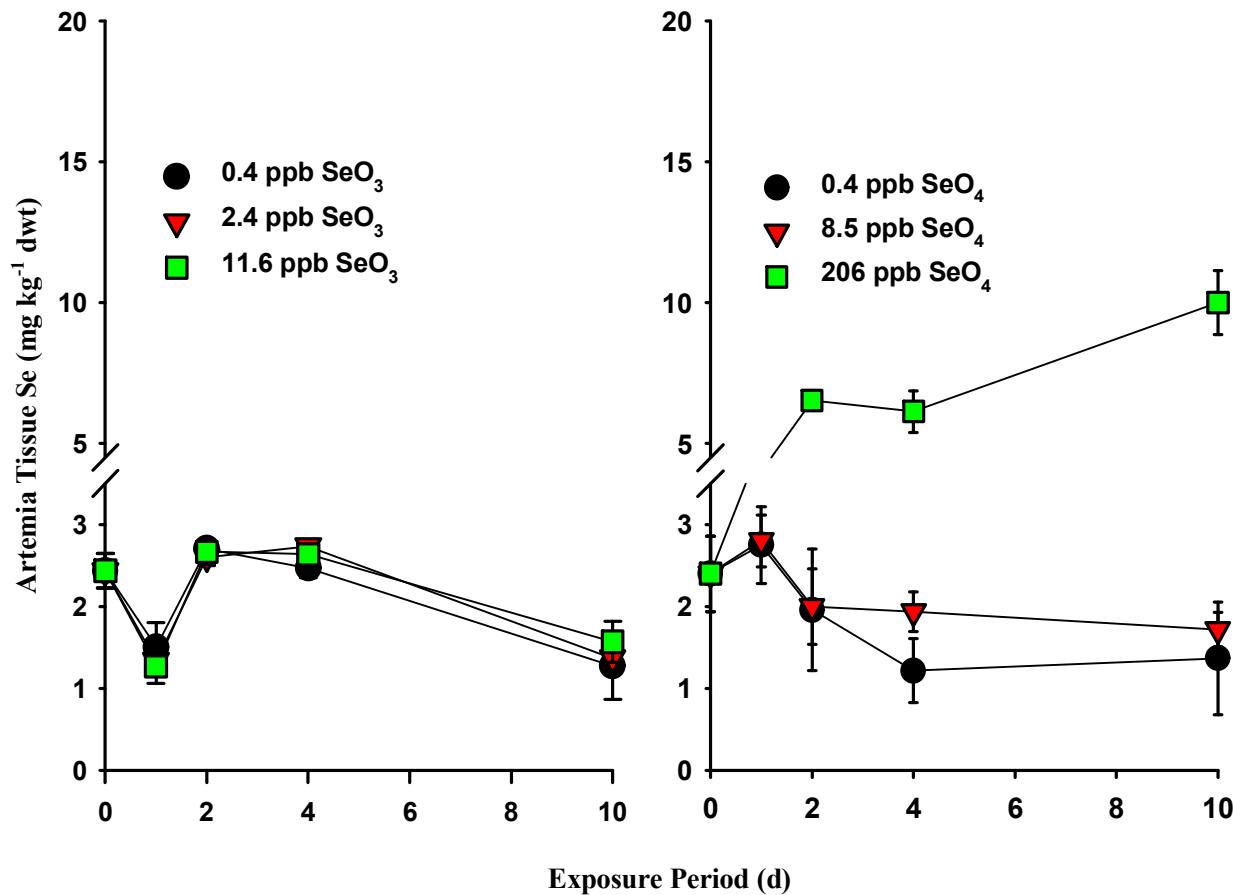


Fig. 4. Shrimp Accumulation of Aqueous Selenite and Selenate. Selenite results appear in the left panel (Test 12) and selenate results are shown in the right panel (Tests 9 and 10). Salinities in the Great Salt Lake water matrix ranged from $82 - 110 \text{ g L}^{-1}$

Table 14. Shrimp Accumulation of Aqueous Selenite.

Test 12, Artemia, Aqueous Uptake SeO ₃		Exp Time (d)	Mean Se ($\mu\text{g g}^{-1}$ dwt)	SD Se ($\mu\text{g g}^{-1}$ dwt)
Observed SeO ₃ ($\mu\text{g L}^{-1}$)	Nominal Se ($\mu\text{g L}^{-1}$)			
0.41	0.5	0	2.433	0.208
0.41	0.5	1	1.500	0.300
0.41	0.5	2	2.700	0.000
0.41	0.5	4	2.467	0.115
0.41	0.5	10	1.270	0.411
2.41	2	1	1.333	0.153
2.41	2	2	2.600	0.100
2.41	2	4	2.733	0.058
2.41	2	10	1.367	0.058
11.61	10	1	1.267	0.208
11.61	10	2	2.667	0.153
11.61	10	4	2.633	0.058
11.61	10	10	1.567	0.252

Table 15. Shrimp Accumulation of Aqueous Selenate in Filtered Great Salt Lake Water. Great Salt Lake water used in test was filtered as described above.

Test 9, Artemia, Aqueous SeO ₄		Exp Time (d)	Mean Se ($\mu\text{g g}^{-1}$ dwt)	SD Se ($\mu\text{g g}^{-1}$ dwt)
Observed SeO ₄ ($\mu\text{g L}^{-1}$)	Nominal Se ($\mu\text{g L}^{-1}$)			
0.4	0.5	0	2.800	0.100
0.4	0.5	1	3.167	0.115
0.4	0.5	2	1.580	0.973
0.4	0.5	4	1.433	0.404
0.4	0.5	10	0.930	0.418
8.2	10	1	3.067	0.115
8.2	10	2	1.600	0.200
8.2	10	4	2.000	0.200
8.2	10	10	1.567	0.153
206	200	1	4.000	0.100
206	200	2	6.537	0.064
206	200	4	6.133	0.746
206	200	10	10.000	1.130
Initial Se for 206ppb 10 d			0.453	0.051

Masses from LET appear incorrect for 3 reps of 200 ppb Se by factor of 22.45

Table 16. Shrimp Accumulation of Aqueous *Selenate* in Unfiltered Great Salt Lake Water.

Test 10, Artemia, Aqueous Unfiltered SeO ₄ , Bacterial Role				
Observed SeO ₄ ($\mu\text{g L}^{-1}$)	Nominal Se ($\mu\text{g L}^{-1}$)	Exp Time (d)	Mean Se ($\mu\text{g g}^{-1}$ dwt)	SD Se ($\mu\text{g g}^{-1}$ dwt)
0.4	0.5	0	2.000	0.200
0.4	0.5	1	2.333	0.115
0.4	0.5	2	2.333	0.058
0.4	0.5	4	0.993	0.272
0.4	0.5	10	1.800	0.656
8.8	10	1	2.533	0.153
8.8	10	2	2.400	0.100
8.8	10	4	1.867	0.306
8.8	10	10	1.867	0.153

Identical results of 1.87 are a correct coincidence.

3.3.4 Shrimp Accumulation of Selenium Via Dietary Exposure

Shrimp accumulation of selenium was greater in exposures with dietary and aqueous selenium (Fig. 5, Tables 17 and 18) than aqueous only treatments (Fig. 4). Apparently, however, speciation of selenium was irrelevant. Both of these conclusions are only applicable to the conditions of the tests and might differ if the dietary selenite exposure period had been extended to 40 days.

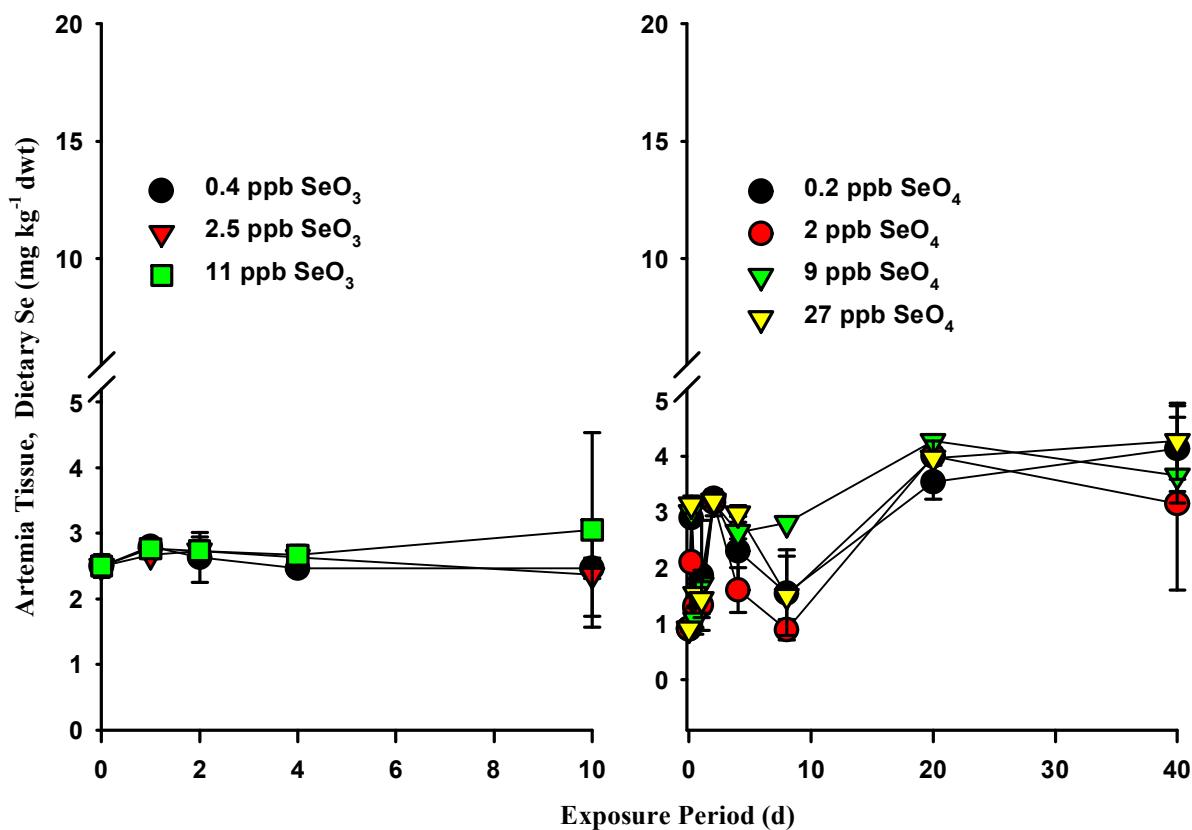


Fig. 5. Shrimp Dietary Accumulation of Selenite and Selenate. Shrimp were exposed to both aqueous and dietary pathways in Great Salt Lake water and algae cultured in selenite (Test 13) or selenate (Test 7). Salinities ranged from 82 – 125 g L⁻¹.

Table 17. Shrimp Dietary Accumulation of Selenite.

Test 13, Artemia, Dietary and Aqueous SeO ₃				
Observed SeO ₃ ($\mu\text{g L}^{-1}$)	Nominal Se ($\mu\text{g L}^{-1}$)	Exp Time (d)	Mean Se ($\mu\text{g g}^{-1}$ dwt)	SD Se ($\mu\text{g g}^{-1}$ dwt)
0.4	0.5	0	2.500	0.173
0.4	0.5	1	2.800	0.100
0.4	0.5	2	2.633	0.379
0.4	0.5	4	2.467	0.115
0.4	0.5	10	2.467	0.153
2.5	2	1	2.667	0.058
2.5	2	2	2.733	0.153
2.5	2	4	2.633	0.058
2.5	2	10	2.367	0.635
10.6	10	1	2.767	0.058
10.6	10	2	2.733	0.208
10.6	10	4	2.667	0.153
10.6	10	10	3.050	1.485

Table 18. Shrimp Dietary Accumulation of *Selenate*.

Test 7, Artemia, Dietary and Aqueous SeO ₄				
Observed SeO ₄ ($\mu\text{g L}^{-1}$)	Nominal Se ($\mu\text{g L}^{-1}$)	Exp Time (d)	Mean Se ($\mu\text{g g}^{-1}$ dwt)	SD Se ($\mu\text{g g}^{-1}$ dwt)
0.4	0.5	0	0.910	0.046
0.4	0.5	0.17	2.900	0.100
0.4	0.5	0.5	1.267	0.351
0.4	0.5	1	1.867	0.981
0.4	0.5	2	3.233	0.153
0.4	0.5	4	2.300	0.624
0.4	0.5	8	1.550	0.778
0.4	0.5	20	3.533	0.306
0.4	0.5	40	4.133	0.764
2.0	2	0.17	2.100	0.794
2.0	2	0.5	1.550	0.071
2.0	2	1	1.333	0.153
2.0	2	2	3.167	0.115
2.0	2	4	1.600	0.400
2.0	2	8	0.893	0.179
2.0	2	20	4.000	0.346
2.0	2	40	3.150	1.061
9.1	10	0.17	3.000	0.000
9.1	10	0.5	1.067	0.252
9.1	10	1	1.700	0.265
9.1	10	2	3.167	0.231
9.1	10	4	2.633	0.115
9.1	10	8	2.800	0.707
9.1	10	20	4.267	0.115
9.1	10	40	3.650	0.495
27.1	27	0.17	3.133	0.153
27.1	27	0.5	1.533	0.252
27.1	27	1	1.433	0.321
27.1	27	2	3.200	0.100
27.1	27	4	2.967	0.153
27.1	27	8	1.500	0.707
27.1	27	20	3.967	0.306
27.1	27	40	4.267	0.681

3.3.5 Bioaccumulation Factors

Absolute accumulation of selenium by algae was concentration dependent, increasing significantly more in treatments with the highest versus the lowest aqueous selenium concentrations. Regardless, the greatest bioaccumulation factors generally occurred in the lowest exposure concentrations (Table 18). Bioaccumulation factors varied approximately 10-fold for selenate versus approximately 3-fold for selenite. Shrimp exposed to selenium via both aqueous and dietary routes (Table 18) strongly regulated their accumulation in all treatments as indicated by stable levels of selenium regardless of selenium concentrations in their algal diet. Thus, bioaccumulation factors for the shrimp are greatest at low selenium concentrations. Selenate was not taken up to a greater extent than selenite. When exposed to selenium through an aqueous route only, shrimp regulated their body burdens up to 80 µg L⁻¹ (Table 19). Compared to algal tissues, shrimp treatments with the lowest concentrations of aqueous selenium (0.2 to 1 µg L⁻¹) resulted in approximately 4-fold greater bioaccumulation factors.

Table 19. Dietary Bioaccumulation Factors (BAF) for Artemia Exposed to Selenate and Selenite.

<i>SeO₄</i> Aqueous, Dunaliella				<i>SeO₄</i> Dietary, Artemia				
Test	Exp time (d)	Se (µg L ⁻¹)	Dunaliella (mg kg ⁻¹)	Mean BAF	Test	Exp time (d)	Artemia (mg kg ⁻¹)	Mean BAF, Diet
6	60	1	1 (0.1)	1,000	7	40	4.1 (0.8)	4.1
6	60	2	0.8 (0.2)	400	7	40	3.2 (1.1)	4.0
6	60	9	1.4 (0.4)	156	7	40	3.7 (0.5)	2.6
6	60	21	1.8 (0.1)	86	7	40	4.3 (0.7)	2.4

<i>SeO₃</i> Aqueous, Dunaliella				<i>SeO₃</i> Dietary, Artemia				
Test	Exp time (d)	Se (µg L ⁻¹)	Dunaliella (mg kg ⁻¹)	Mean BAF	Test	Exp time (d)	Artemia (mg kg ⁻¹)	Mean BAF, Diet
11	12	0.5	0.3 (0.2)	500	13	10	2.5 (0.2)	10.0
11	12	2.8	1.9 (0.2)	679	13	10	2.9 (0.7)	1.5
11	12	12.2	2.1 (0.1)	172	13	10	3.1 (1.5)	1.4

Table 20. Aqueous Bioaccumulation Factors (BAF) for Artemia Exposed to Selenate and Selenite.

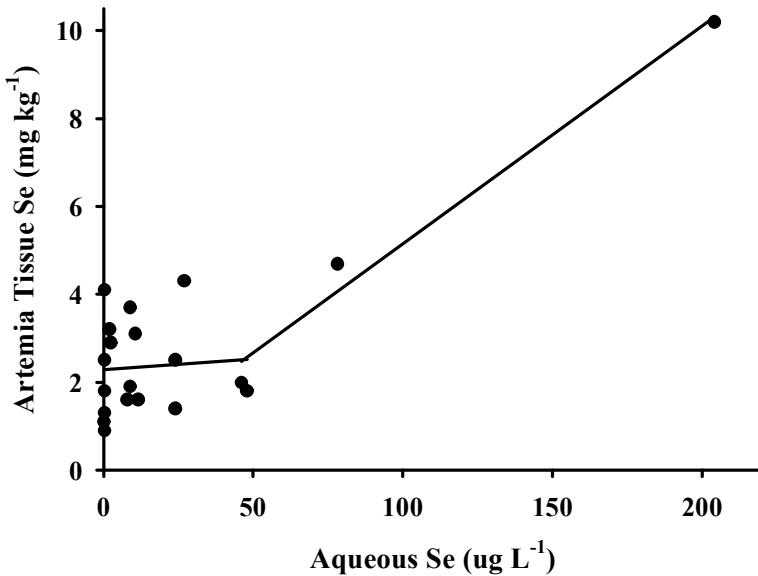
<i>SeO₄</i> Aqueous, Artemia				
Test	Exp time (d)	Se ($\mu\text{g L}^{-1}$)	Artemia (mg kg^{-1})	Mean BAF, Aq only
3	10	0.2	1.1 (0.0)	5,500
9	10	0.4	0.9 (0.4)	2,250
10	10	0.4	1.8 (0.7)	4,500
9	10	8	1.6 (0.2)	200
10	10	9	1.9 (0.2)	211
3	10	24	2.5 (1.6)	104
3	10	48	1.8 (0.4)	38
4	4	80	4.5 (2.1)	56
9	10	206	10 (1.1)	49

<i>SeO₃</i> Aqueous, Artemia				
Test	Exp time (d)	Se ($\mu\text{g L}^{-1}$)	Artemia (mg kg^{-1})	Mean BAF, Aq only
12	10	0.4	1.3 (0.4)	3250
12	10	2.4	1.4 (0.1)	583
12	10	11.6	1.6 (0.3)	138

3.3.6 Relationship Between Shrimp Accumulation and Aqueous Selenium

Segmented regression analysis of the relationship between shrimp accumulation of selenium and aqueous selenium indicate that an inflection point between data having a significant dose response relationship and data lacking such a relationship occurs at $48.8 \mu\text{g L}^{-1}$. The intercept of the dose-response curve with the suggested maximal tissue selenium concentration of 5 mg kg^{-1} is 102 $\mu\text{g L}^{-1}$.

Fig. 6. Segmented Regression Analysis (Hockey Stick) of *Artemia* Accumulation of Selenium. Data come from maximal exposure periods after tissue concentrations reached asymptotes. Data include tests with selenite and selenate from both aqueous-only and aqueous-and-dietary exposure routes.



3.3.7 Miscellaneous Results

A 24-h exposure of *Dunaliella viridis* was conducted to evaluate whether test matrix concentrations changed between solution renewals (Table 20). Results under these conditions suggest no consistent pattern in selenium concentration before and after exposure.

Table 21. Selenium Concentrations in Test Solutions Before and After 24-Hour Exposures.

Test 8, Dunaliella, Matrix Change in SeO ₄ in 24-h			
Exposure	Observed SeO ₄ ($\mu\text{g L}^{-1}$)	Nominal Se ($\mu\text{g L}^{-1}$)	Exp Time (d)
Before	0.7	0.5	1
After	0.0	0.5	1
Before	1.7	2	1
After	1.9	2	1
Before	7.5	10	1
After	7.6	10	1

4. DISCUSSION

Tissue concentrations in Artemia provided nutritional selenium during rearing (e.g., YCT and freeze-dried rotifers) did not increase during 10 day exposures to aqueous selenium below 12 $\mu\text{g L}^{-1}$ (Fig. 3), regardless of the chemical species of selenium. In initial tests, brine shrimp diet during rearing lacked adequate selenium. Interestingly, they acquired the same stable tissue concentrations as later tests within 6 days (Fig. 2). Algal tissue appeared to reach an asymptote after approximately 8 days of exposure to selenite. In contrast, algae exposed to selenate required between 20 to 45 days to achieve stable tissue concentrations (Fig. 4). Thus, unlike brine shrimp, it appears that algae take up selenite more rapidly than selenate. Dietary exposures of brine shrimp (with concurrent water exposure) resulted in slightly higher tissue levels than water-only exposures (Figure 5, Tables 19 and 20). Exposure in the laboratory resulted in levels that are similar to those in brine shrimp collected from the Great Salt Lake (Brix et al. 2003). For selenium concentrations $\leq 27 \mu\text{g L}^{-1}$, shrimp tissue accumulations were always less than a bird dietary threshold of 5 mg kg⁻¹ dry weight. Figure 6 suggests that brine shrimp regulate bioaccumulation of this essential trace nutrient in Great Salt Lake waters if selenite and selenate concentrations are less than 48 $\mu\text{g L}^{-1}$. Above 48 $\mu\text{g L}^{-1}$, brine shrimp demonstrate a linear dose-response behavior ($R^2 = 98\%$). However, the predictive relationship between dose and tissue accumulation is tenuous because only 3 data points contributed to the dose-response portion of the regression curve. Nonetheless, below selenium concentrations of 48 $\mu\text{g L}^{-1}$, it appears that brine shrimp strongly regulate their uptake of selenium regardless of the chemical species of selenium or whether exposure was aqueous or dietary.

5. REFERENCES

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6. APPENDICES

APPENDIX A

Analysis of Selenium Concentration in Shrimp Foods

Table 6.A. Selenium Concentration in Shrimp Foods

LET ID	Submitter ID	Se $\mu\text{g/g}$ Dry Wt	Mean $\mu\text{g/g}$ DryWt	SD $\mu\text{g/g}$ DryWt
L06060555	YCT1	0.72	0.72	0.00
L06060556	YCT2	0.72		
L06060557	ROT1	4	4.05	
L06060558	ROT2	4.1		0.07

YCT = yeast cerophyl-trout chow mixtures (U.S. EPA 2000). ROT = freeze-dried rotifers.

APPENDIX B
Analysis of Great Salt Lake Waters

Table 6.B. Composition of Great Salt Lake Waters Used in Study.

Collection date	7/24/2005	9/15/2005	11/21/2005	3/28/2006	6/20/2006
Fluoride *	<11	<DL	<DL	<DL	<DL
Chloride	72934	67464	73667	67068	50292
Nitrate *	<64	<DL	<DL	<DL	<DL
Phosphate *	<213	<DL	<DL	<DL	<DL
Sulfate	8508	8447	8925	8207	6044
Calcium	228	216	234	223	181
Magnesium	4183	3972	4514	3910	3074
Sodium	41120	38266	41626	38887	29743
Potassium	2530	2528	3009	2547	1911
Cadmium	0.40	0.29	0.35	0.13	0.18
Copper ($\mu\text{g L}^{-1}$)	0.25	8.41	0.18	0.18	0.12
Iron	n.m.	1.06	0.88	1.41	0.66
Lead	1.62	n.m.	1.29	0.86	0.85
Zinc	0.06	78.50	0.09	0.07	0.06
DOC	43.07	n.m.	48.12	41.84	29.77
pH	8.3	8.4	8.12	8.35	8.21
Salinity (g L^{-1})	120	123	135	120	89

Units are mg L^{-1} unless indicated otherwise. * = less than detection limit *dilution factor.
Metals and cations analyzed by Flame AA DOC = dissolved organic carbon, 1 μm filtration.

APPENDIX C

Tables 6.C. Tissue Accumulation of Selenium: Raw Data From Individual Replicates in All Tests

Test 1, Tissue Se Concentrations, Dunaliella

Raw Data		Nominal Se (µg/L)	Exp Time (d)	Se µg/g Dry Wt	Mean µg/g DryWt	SD µg/g DryWt
LET I.D.	Submitter I.D.					
L05090083	UW 9/05-DVT-SE0-0-1/3	0	0	0.0000	0.000	0.000
L05090084	UW 9/05-DVT-SE0-0-2/3	0	0	0.0000		
L05090173	UW 9/05-DVT-SE0-0-3/3	0	0	0.0000		
L05090085	UW 9/05-DVT-SE1-0-1/3	1	0	0.0000	0.000	0.000
L05090086	UW 9/05-DVT-SE1-0-2/3	1	0	0.0000		
L05090087	UW 9/05-DVT-SE1-0-3/3	1	0	0.0000		
L05090101	UW 9/05-DVT-SE1-4-1/3	1	4	0.0000	0.000	0.000
L05090102	UW 9/05-DVT-SE1-4-2/3	1	4	0.0000		
L05090106	UW 9/05-DVT-SE1-4-3/3	1	4	0.0000		
L05090120	UW 9/05-DVT-SE1-24-1/3	1	24	0.0000	0.000	0.000
L05090121	UW 9/05-DVT-SE1-24-2/3	1	24	0.0000		
L05090122	UW 9/05-DVT-SE1-24-3/3	1	24	0.0000		
L05090139	UW 9/05-DVT-SE1-48-1/3	1	48	0.0000	0.000	0.000
L05090140	UW 9/05-DVT-SE1-48-2/3	1	48	0.0000		
L05090141	UW 9/05-DVT-SE1-48-3/3	1	48	0.0000		
L05090158	UW 9/05-DVT-SE1-96-1/3	1	96	0.0000	0.000	0.000
L05090159	UW 9/05-DVT-SE1-96-2/3	1	96	0.0000		
L05090160	UW 9/05-DVT-SE1-96-3/3	1	96	0.0000		
L05090088	UW 9/05-DVT-SE9-0-1/3	9	0	0.0111	0.005	0.006
L05090089	UW 9/05-DVT-SE9-0-2/3	9	0	0.0000		
L05090090	UW 9/05-DVT-SE9-0-3/3	9	0	0.0026		
L05090107	UW 9/05-DVT-SE9-4-1/3	9	4	0.0157	0.005	0.009
L05090108	UW 9/05-DVT-SE9-4-2/3	9	4	0.0000		
L05090109	UW 9/05-DVT-SE9-4-3/3	9	4	0.0000		
L05090123	UW 9/05-DVT-SE9-24-1/3	9	24	0.0034	0.006	0.003
L05090124	UW 9/05-DVT-SE9-24-2/3	9	24	0.0041		
L05090125	UW 9/05-DVT-SE9-24-3/3	9	24	0.0097		
L05090142	UW 9/05-DVT-SE9-48-1/3	9	48	0.0150	0.011	0.007
L05090143	UW 9/05-DVT-SE9-48-2/3	9	48	0.0148		
L05090144	UW 9/05-DVT-SE9-48-3/3	9	48	0.0034		
L05090161	UW 9/05-DVT-SE9-96-1/3	9	96	0.0102	0.012	0.008
L05090162	UW 9/05-DVT-SE9-96-2/3	9	96	0.0042		
L05090163	UW 9/05-DVT-SE9-96-3/3	9	96	0.0206		
L05090092	UW 9/05-DVT-SE18-0-1/3	18	0	0.0017	0.001	0.001
L05090093	UW 9/05-DVT-SE18-0-2/3	18	0	0.0011		
L05090094	UW 9/05-DVT-SE18-0-3/3	18	0	0.0000		
L05090110	UW 9/05-DVT-SE18-4-1/3	18	4	0.0000	0.000	0.001
L05090111	UW 9/05-DVT-SE18-4-2/3	18	4	0.0000		
L05090112	UW 9/05-DVT-SE18-4-3/3	18	4	0.0013		
L05090126	UW 9/05-DVT-SE18-24-1/3	18	24	0.0020	0.001	0.001

Test 1, Tissue Se Concentrations, Dunaliella (cont.)

Raw Data		Nominal Se ($\mu\text{g/L}$)	Exp Time (d)	$\mu\text{g/g}$	Mean $\mu\text{g/g}$	SD $\mu\text{g/g}$
LET I.D.	Submitter I.D.			Dry Wt	DryWt	DryWt
L05090130	UW 9/05-DVT-SE18-24-2/3	18	24	0.0006		
L05090131	UW 9/05-DVT-SE18-24-3/3	18	24	0.0010		
L05090145	UW 9/05-DVT-SE18-48-1/3	18	48	0.0000	0.003	0.003
L05090146	UW 9/05-DVT-SE18-48-2/3	18	48	0.0030		
L05090147	UW 9/05-DVT-SE18-48-3/3	18	48	0.0059		
L05090164	UW 9/05-DVT-SE18-96-1/3	18	96	0.0055	0.007	0.002
L05090165	UW 9/05-DVT-SE18-96-2/3	18	96	0.0061		
L05090166	UW 9/05-DVT-SE18-96-3/3	18	96	0.0086		
L05090095	UW 9/05-DVT-SE27-0-1/3	27	0	0.0000	0.005	0.007
L05090096	UW 9/05-DVT-SE27-0-2/3	27	0	0.0126		
L05090097	UW 9/05-DVT-SE27-0-3/3	27	0	0.0016		
L05090114	UW 9/05-DVT-SE27-4-1/3	27	4	0.0170	0.014	0.013
L05090115	UW 9/05-DVT-SE27-4-2/3	27	4	0.0000		
L05090116	UW 9/05-DVT-SE27-4-3/3	27	4	0.0250		
L05090132	UW 9/05-DVT-SE27-24-1/3	27	24	0.0179	0.015	0.013
L05090133	UW 9/05-DVT-SE27-24-2/3	27	24	0.0000		
L05090134	UW 9/05-DVT-SE27-24-3/3	27	24	0.0256		
L05090148	UW 9/05-DVT-SE27-48-1/3	27	48	0.0321	0.039	0.008
L05090149	UW 9/05-DVT-SE27-48-2/3	27	48	0.0478		
L05090150	UW 9/05-DVT-SE27-48-3/3	27	48	0.0356		
L05090167	UW 9/05-DVT-SE27-96-1/3	27	96	0.0223	0.022	0.008
L05090168	UW 9/05-DVT-SE27-96-2/3	27	96	0.0304		
L05090169	UW 9/05-DVT-SE27-96-3/3	27	96	0.0142		
L05090098	UW 9/05-DVT-SE54-0-1/3	44	0	0.0000	0.001	0.002
L05090099	UW 9/05-DVT-SE54-0-2/3	54	0	0.0000		
L05090100	UW 9/05-DVT-SE54-0-3/3	54	0	0.0031		
L05090117	UW 9/05-DVT-SE54-4-1/3	54	4	0.0000	0.000	0.000
L05090118	UW 9/05-DVT-SE54-4-2/3	54	4	0.0000		
L05090119	UW 9/05-DVT-SE54-4-3/3	54	4	0.0000		
L05090136	UW 9/05-DVT-SE54-24-1/3	54	24	0.0000	0.000	0.000
L05090137	UW 9/05-DVT-SE54-24-2/3	54	24	0.0000		
L05090138	UW 9/05-DVT-SE54-24-3/3	54	24	0.0000		
L05090154	UW 9/05-DVT-SE54-48-1/3	54	48	0.0149	0.020	0.006
L05090155	UW 9/05-DVT-SE54-48-2/3	54	48	0.0266		
L05090156	UW 9/05-DVT-SE54-48-3/3	54	48	0.0188		
L05090170	UW 9/05-DVT-SE54-96-1/3	54	96	0.0610	0.068	0.007
L05090171	UW 9/05-DVT-SE54-96-2/3	54	96	0.0669		
L05090172	UW 9/05-DVT-SE54-96-3/3	54	96	0.0746		

Test 2, Tissue Se concentrations, Artemia

Raw Data		Nominal Se ($\mu\text{g/L}$)	Exp Time (d)	$\mu\text{g/g}$	Mean $\mu\text{g/g}$	SD $\mu\text{g/g}$
LET I.D.	Submitter I.D.			Dry Wt	DryWt	DryWt
L05100002	UW 10/05-AFT-A-SE1-0-1/3	1	0	0.17	0.137	0.058
L05100003	UW 10/05-AFT-A-SE1-0-2/3	1	0	0.17		
L05100004	UW 10/05-AFT-A-SE1-0-3/3	1	0	0.07		
L05100012	UW 10/05-AFT-A-SE1-24-1/3	1	1	0.1	0.075	0.035
L05100013	UW 10/05-AFT-A-SE1-24-2/3	1	1	0.05		
L05100014	UW 10/05-AFT-A-SE1-24-3/3	1	1	<0.05		
L05100024	UW 10/05-AFT-A-SE1-96-1/3	1	4	0.09	0.097	0.006
L05100025	UW 10/05-AFT-A-SE1-96-2/3	1	4	0.1		
L05100026	UW 10/05-AFT-A-SE1-96-3/3	1	4	0.1		
L05100006	UW 10/05-AFT-A-SE27-0-1/3	27	0	0.1	0.177	0.071
L05100007	UW 10/05-AFT-A-SE27-0-2/3	27	0	0.24		
L05100008	UW 10/05-AFT-A-SE27-0-3/3	27	0	0.19		
L05100015	UW 10/05-AFT-A-SE27-24-1/3	27	1	0.1	0.100	0.000
L05100016	UW 10/05-AFT-A-SE27-24-2/3	27	1	0.1		
L05100017	UW 10/05-AFT-A-SE27-24-3/3	27	1	0.1		
L05100028	UW 10/05-AFT-A-SE27-96-1/3	27	4	0.1	0.093	0.012
L05100029	UW 10/05-AFT-A-SE27-96-2/3	27	4	0.1		
L05100030	UW 10/05-AFT-A-SE27-96-3/3	27	4	0.08		
L05100009	UW 10/05-AFT-A-SE54-0-1/3	54	0	0.22	0.163	0.067
L05100010	UW 10/05-AFT-A-SE54-0-2/3	54	0	0.09		
L05100011	UW 10/05-AFT-A-SE54-0-3/3	54	0	0.18		
L05100018	UW 10/05-AFT-A-SE54-24-1/3	54	1	0.06	0.110	0.056
L05100019	UW 10/05-AFT-A-SE54-24-2/3	54	1	0.1		
L05100020	UW 10/05-AFT-A-SE54-24-3/3	54	1	0.17		
L05100031	UW 10/05-AFT-A-SE54-96-1/3	54	4	0.1	0.087	0.023
L05100032	UW 10/05-AFT-A-SE54-96-2/3	54	4	0.06		
L05100033	UW 10/05-AFT-A-SE54-96-3/3	54	4	0.1		

Test 3 & 4, Tissue Se Concentrations, Artemia

Raw Data	Submitter I.D.	Nominal Se (µg/L)	Exp Time (d)	µg/g Dry Wt	Mean µg/g DryWt	SD µg/g DryWt
LET I.D.						
L05100159	100 TAS 10	1	0	0.19	0.270	0.114
L05100160	101 TAS 10	1	0	0.4		
L05100161	102 TAS 10	1	0	0.22		
L05100162	103 TAS 14	1	0.17	0.29	0.270	0.044
L05100163	104 TAS 14	1	0.17	0.3		
L05100164	105 TAS 14	1	0.17	0.22		
L05100165	106 TAS 148	1	2	0.1	0.180	0.072
L05100166	107 TAS 148	1	2	0.2		
L05100167	108 TAS 148	1	2	0.24		
L05100168	109 TAS 16d	1	6	1.6	2.733	1.266
L05100169	110 TAS 16d	1	6	2.5		
L05100170	111 TAS 16d	1	6	4.1		
L05100200	112 TAS 18d	1	8	1.3	1.667	0.404
L05100201	113 TAS 18d	1	8	2.1		
L05100202	114 TAS 18d	1	8	1.6		
L05100203	115 TAS 110d	1	10	reject b/c	1.100	#DIV/0!
L05100204	116 TAS 110d	1	10	low mass		
L05100205	117 TAS 110d	1	10	1.1		
L05100172	127 TAS 274	27	0.17	0.36	0.407	0.057
L05100173	128 TAS 274	27	0.17	0.39		
L05100174	129 TAS 274	27	0.17	0.47		
L05100175	130 TAS 2748	27	2	0.26	0.197	0.055
L05100176	131 TAS 2748	27	2	0.17		
L05100177	132 TAS 2748	27	2	0.16		
L05100178	133 TAS 276d	27	6	2.8	2.933	0.611
L05100179	134 TAS 276d	27	6	3.6		
L05100180	135 TAS 276d	27	6	2.4		
L05100209	136 TAS 278d	27	8	2.1	2.367	0.462
L05100210	137 TAS 278d	27	8	2.1		
L05100211	138 TAS 278d	27	8	2.9		
L05100212	139 TAS 2710d	27	10	3.6	2.500	1.556
L05100214	141 TAS 2710d	27	10	1.4		
L05100181	152 TAS 544	54	0.17	0.51	0.497	0.081
L05100182	153 TAS 544	54	0.17	0.41		
L05100186	154 TAS 544	54	0.17	0.57		
L05100187	155 TAS 5448	54	2	0.16	0.193	0.031
L05100188	156 TAS 5448	54	2	0.22		
L05100189	157 TAS 5448	54	2	0.2		
L05100190	158 TAS 546d	54	6	3.4	3.100	0.265
L05100191	159 TAS 546d	54	6	3		
L05100192	160 TAS 546d	54	6	2.9		
L05100193	161 TAS 548d	54	8	2.4	2.400	0.200
L05100194	162 TAS 548d	54	8	2.6		
L05100195	163 TAS 548d	54	8	2.2		
L05100196	164 TAS 5410d	54	10	2.1	1.767	0.351
L05100197	165 TAS 5410d	54	10	1.8		
L05100198	166 TAS 5410d	54	10	1.4		
L05100215	175 TAS 10824	108	1	4.5	3.833	1.069
L05100216	176 TAS 10824	108	1	4.4		
L05100217	177 TAS 10824	108	1	2.6		
L05100218	178 TAS 10896	108	4	8.1	4.500	3.132
L05100219	179 TAS 10896	108	4	3		
L05100220	180 TAS 10896	108	4	2.4		

Test 5, Tissue Se Concentrations, Dunaliella

Raw Data		Nominal Se ($\mu\text{g/L}$)	SO4 (mg/L)	Exp Time (d)	$\mu\text{g/g}$ Dry Wt	Mean $\mu\text{g/g}$	SD $\mu\text{g/g}$
LET I.D.	Submitter I.D.				DryWt	DryWt	DryWt
L05120012	612DTS242.5	2	2.5	4	0.00	0.000	0.000
L05120013	613DTS242.5	2	2.5	4	0.00		
L05120014	614DTS242.5	2	2.5	4	0.00		
L05120084	630DTS282.5	2	2.5	8	0.00	0.000	0.000
L05120085	631DTS282.5	2	2.5	8	0.00		
L05120086	632DTS282.5	2	2.5	8	0.00		
L05120033	648DTS2122.5	2	2.5	12	0.00	0.000	0.000
L05120034	650DTS2122.5	2	2.5	12	0.00		
L05120065	666DTS2202.5	2	2.5	20	0.00	0.000	0.000
L05120067	668DTS2202.5	2	2.5	20	0.00		
L05120015	615DTS1042.5	10	2.5	4	0.07	0.077	0.006
L05120016	616DTS1042.5	10	2.5	4	0.08		
L05120017	617DTS1042.5	10	2.5	4	0.08		
L05120087	633DTS1082.5	10	2.5	8	0.00	0.027	0.046
L05120088	634DTS1082.5	10	2.5	8	0.08		
L05120089	635DTS1082.5	10	2.5	8	0.00		
L05120035	651DTS10122.5	10	2.5	12	0.00	0.000	0.000
L05120036	652DTS10122.5	10	2.5	12	0.00		
L05120037	653DTS10122.5	10	2.5	12	0.00		
L05120068	669DTS10202.5	10	2.5	20	0.00	0.000	0.000
L05120069	670DTS10202.5	10	2.5	20	0.00		
L05120018	618DTS10425	10	25	4	0.10	0.033	0.058
L05120019	619DTS10425	10	25	4	0.00		
L05120020	620DTS10425	10	25	4	0.00		
L05120090	636DTS10825	10	25	8	0.00	0.033	0.058
L05120091	637DTS10825	10	25	8	0.00		
L05120092	638DTS10825	10	25	8	0.10		
L05120038	654DTS101225	10	25	12	0.10	0.167	0.058
L05120039	655DTS101225	10	25	12	0.20		
L05120040	656DTS101225	10	25	12	0.20		
L05120070	671DTS102025	10	25	20	0.00	0.000	0.000
L05120071	672DTS102025	10	25	20	0.00		
L05120053	600DTS008	0.5	8000	0	0.00	0.000	0.000
L05120054	601DTS008	0.5	8000	0	0.00		
L05120055	602DTS008	0.5	8000	0	0.00		
L05120002	603DTS048	0.5	8000	4	0.07	0.023	0.040
L05120003	604DTS048	0.5	8000	4	0.00		
L05120004	605DTS048	0.5	8000	4	0.00		
L05120075	621DTS088	0.5	8000	8	0.06	0.020	0.035
L05120076	622DTS088	0.5	8000	8	0.00		

Test 5, Tissue Se Concentrations, Dunaliella (Cont.)

Raw Data		Nominal Se (µg/L)	SO4 (mg/L)	Exp Time (d)	µg/g Dry Wt	Mean µg/g DryWt	SD µg/g DryWt
LET I.D.	Submitter I.D.						
L05120077	623DTS088	0.5	8000	8	0.00		
L05120021	639DTS0128	0.5	8000	12	0.30	0.133	0.153
L05120025	640DTS0128	0.5	8000	12	0.10		
L05120026	641DTS0128	0.5	8000	12	0.00		
L05120056	657DTS0208	0.5	8000	20	0.25	0.183	0.161
L05120057	658DTS0208	0.5	8000	20	0.30		
L05120058	659DTS0208	0.5	8000	20	0.00		
L05120005	606DTS248	2	8000	4	0.00	0.000	0.000
L05120006	607DTS248	2	8000	4	0.00		
L05120007	608DTS248	2	8000	4	0.00		
L05120078	624DTS288	2	8000	8	0.07	0.070	0.000
L05120079	625DTS288	2	8000	8	0.07		
L05120080	626DTS288	2	8000	8	0.09		
L05120027	642DTS2128	2	8000	12	0.00	0.000	0.000
L05120028	643DTS2128	2	8000	12	0.00		
L05120029	644DTS2128	2	8000	12	0.00		
L05120059	660DTS2208	2	8000	20	0.00	0.000	0.000
L05120060	661DTS2208	2	8000	20	0.00		
L05120061	662DTS2208	2	8000	20	0.00		
L05120008	609DTS1048	10	8000	4	0.00	0.030	0.042
L05120009	610DTS1048	10	8000	4	0.06		
L05120010	611DTS1048	10	8000	4	0.05		
L05120081	627DTS1088	10	8000	8	0.07	0.085	0.021
L05120082	628DTS1088	10	8000	8	0.10		
L05120083	629DTS1088	10	8000	8	0.10		
L05120030	645DTS10128	10	8000	12	0.10	0.050	0.071
L05120031	646DTS10128	10	8000	12	0.00		
L05120032	647DTS10128	10	8000	12	0.00		
L05120062	663DTS10208	10	8000	20	0.23	0.215	0.021
L05120063	664DTS10208	10	8000	20	0.20		
L05120064	665DTS10208	10	8000	20	0.28		

Test 6, Tissue Se Concentrations, Dunaliella

Raw Data		Nominal Se ($\mu\text{g/L}$)	Exp Time (d)	$\mu\text{g/g}$	Mean $\mu\text{g/g}$	SD $\mu\text{g/g}$
LET I.D.	Submitter I.D.			Dry Wt	DryWt	DryWt
L06040113	1000DATS045d	0	45	1.3	0.950	0.321
L06040117	1001DATS045d	0	45	0.67		
L06040118	1002DATS045d	0	45	0.88		
L06040125	1019DATS060d	0	60	0.98	1.040	0.085
L06040126	1020DATS060d	0	60	1.1		
L06040114	1003DATS245d	2	45	1.1	0.847	0.223
L06040119	1004DATS245d	2	45	0.68		
L06040120	1005DATS245d	2	45	0.76		
L06040127	1022DATS260d	2	60	0.67	0.830	0.226
L06040128	1023DATS260d	2	60	0.99		
L06040115	1006DATS1045d	10	45	1.4	1.077	0.400
L06040121	1007DATS1045d	10	45	1.2		
L06040122	1008DATS1045d	10	45	0.63		
L06040129	1025DATS1060d	10	60	1.7	1.400	0.424
L06040130	1026DATS1060d	10	60	1.1		
L06040123	1010DATS2745d	27	45	1.7	1.433	0.306
L06040124	1011DATS2745d	27	45	1.5		
L06040116	1009DATS2745d	27	45	1.1		
L06040132	1028DATS2760d	27	60	1.8	1.750	0.071
L06040133	1029DATS2760d	27	60	1.7		

Test 7, Tissue Se Concentrations, Artemia

Raw Data		Nominal Se ($\mu\text{g/L}$)	Exp Time (d)	$\mu\text{g/g}$ Dry Wt	Mean $\mu\text{g/g}$	SD $\mu\text{g/g}$
LET I.D.	Submitter I.D.			DryWt	DryWt	
L06050190	800ADTS00	0	0	0.96	0.910	0.046
L06050191	801ADTS00	0	0	0.87		
L06050192	802ADTS00	0	0	0.9		
L06050193	812ADTS04h	0	0.17	2.8	2.900	0.100
L06050194	813ADTS04h	0	0.17	3		
L06050195	814ADTS04h	0	0.17	2.9		
L06050205	824ADTS012h	0	0.5	1.6	1.267	0.351
L06050206	825ADTS012h	0	0.5	1.3		
L06050207	826ADTS012h	0	0.5	0.9		
L06050221	836ADTS024h	0	1	3	1.867	0.981
L06050222	837ADTS024h	0	1	1.3		
L06050223	838ADTS024h	0	1	1.3		
L06050233	848ADTS02d	0	2	3.4	3.233	0.153
L06050238	849ADTS02d	0	2	3.2		
L06050239	850ADTS02d	0	2	3.1		
L06050250	860ADTS04d	0	4	2.8	2.300	0.624
L06050251	861ADTS04d	0	4	2.5		
L06050252	862ADTS04d	0	4	1.6		
L06050265	872ADTS08d	0	8	2.1	1.550	0.778
L06050266	873ADTS08d	0	8	<0.05		
L06050267	874ADTS08d	0	8	1		
L06050278	884ADTS020d	0	20	3.6	3.533	0.306
L06050279	885ADTS020d	0	20	3.8		
L06050280	886ADTS020d	0	20	3.2		
L06050293	896ADTS040d	0	40	4.8	4.133	0.764
L06050294	897ADTS040d	0	40	4.3		
L06050295	898ADTS040d	0	40	3.3		
L06050196	815ADTS24h	2	0.17	1.5	2.100	0.794
L06050197	816ADTS24h	2	0.17	1.8		
L06050198	817ADTS24h	2	0.17	3		
L06050208	827ADTS212h	2	0.5	0.88	1.550	0.071
L06050209	828ADTS212h	2	0.5	1.5		
L06050214	829ADTS212h	2	0.5	1.6		
L06050224	839ADTS224h	2	1	1.2	1.333	0.153
L06050225	840ADTS224h	2	1	1.3		
L06050226	841ADTS224h	2	1	1.5		
L06050240	851ADTS22d	2	2	3.1	3.167	0.115
L06050241	852ADTS22d	2	2	3.1		
L06050242	853ADTS22d	2	2	3.3		
L06050253	863ADTS24d	2	4	2	1.600	0.400

Test 7, Tissue Se Concentrations, Artemia (Cont.)

Raw Data		Nominal Se (µg/L)	Exp Time (d)	µg/g Dry Wt	Mean µg/g DryWt	SD µg/g DryWt
LET I.D.	Submitter I.D.					
L06050254	864ADTS24d	2	4	1.2		
L06050255	865ADTS24d	2	4	1.6		
L06050268	875ADTS28d	2	8	0.8	0.893	0.179
L06050269	876ADTS28d	2	8	1.1		
L06050270	877ADTS28d	2	8	0.78		
L06050281	887ADTS220d	2	20	3.8	4.000	0.346
L06050282	888ADTS220d	2	20	3.8		
L06050286	889ADTS220d	2	20	4.4		
L06050296	899ADTS240d	2	40	2.4	3.150	1.061
				Reject, low mass		
L06050297	900ADTS240d	2	40	3.9		
L06050298	901ADTS240d	2	40	3.9		
L06050199	818ADTS104h	10	0.17	3	3.000	0.000
L06050200	819ADTS104h	10	0.17	3		
L06050201	820ADTS104h	10	0.17	3		
L06050215	830ADTS1012h	10	0.5	0.8	1.067	0.252
L06050216	831ADTS1012h	10	0.5	1.1		
L06050217	832ADTS1012h	10	0.5	1.3		
L06050227	842ADTS1024h	10	1	1.5	1.700	0.265
L06050228	843ADTS1024h	10	1	2		
L06050229	844ADTS1024h	10	1	1.6		
L06050244	854ADTS102d	10	2	2.9	3.167	0.231
L06050245	855ADTS102d	10	2	3.3		
L06050246	856ADTS102d	10	2	3.3		
L06050256	866ADTS104d	10	4	2.5	2.633	0.115
L06050257	867ADTS104d	10	4	2.7		
L06050258	868ADTS104d	10	4	2.7		
L06050272	878ADTS108d	10	8	0.42	2.800	0.000
L06050273	879ADTS108d	10	8	<2	Used only 1 value	
L06050274	880ADTS108d	10	8	2.8		
L06050287	890ADTS1020d	10	20	4.2	4.267	0.115
L06050288	891ADTS1020d	10	20	4.4		
L06050289	892ADTS1020d	10	20	4.2		
L06050299	902ADTS1040d	10	40	<5	3.650	0.495
L06050300	903ADTS1040d	10	40	3.3		
L06050301	904ADTS1040d	10	40	4		
L06050202	821ADTS274h	27	0.17	3.1	3.133	0.153
L06050203	822ADTS274h	27	0.17	3		
L06050204	823ADTS274h	27	0.17	3.3		
L06050218	833ADTS2712h	27	0.5	1.5	1.533	0.252
L06050219	834ADTS2712h	27	0.5	1.3		
L06050220	835ADTS2712h	27	0.5	1.8		
L06050230	845ADTS2724h	27	1	1.3	1.433	0.321
L06050231	846ADTS2724h	27	1	1.2		
L06050232	847ADTS2724h	27	1	1.8		
L06050247	857ADTS272d	27	2	3.3	3.200	0.100
L06050248	858ADTS272d	27	2	3.1		
L06050249	859ADTS272d	27	2	3.2		
L06050262	869ADTS274d	27	4	2.8	2.967	0.153
L06050263	870ADTS274d	27	4	3		
L06050264	871ADTS274d	27	4	3.1		
L06050275	881ADTS278d	27	8	0.26	1.500	0.707

Test 7, Tissue Se Concentrations, Artemia (Concl.)

Raw Data		Nominal Se (µg/L)	Exp Time (d)	µg/g Dry Wt	Mean µg/g DryWt	SD µg/g DryWt
LET I.D.	Submitter I.D.					
L06050276	882ADTS278d	27	8	2		
L06050277	883ADTS278d	27	8	1		
L06050290	893ADTS2720d	27	20	3.7	3.967	0.306
L06050291	894ADTS2720d	27	20	4.3		
L06050292	895ADTS2720d	27	20	3.9		
L06050302	905ADTS2740d	27	40	3.5	4.267	0.681
L06050303	906ADTS2740d	27	40	4.8		
L06050304	907ADTS2740d	27	40	4.5		

Test 8, Tissue Se Concentrations, Dunaliella

Raw Data		Nominal Se (µg/L)	Exp Time (d)	µg/g	Mean µg/g	SD µg/g
LET I.D.	Submitter I.D.			Dry Wt	DryWt	DryWt
L06060560	1100DATS024h	0.36		1	0.2	0.457
L06060561	1101DATS024h	0.36		1	0.67	
L06060562	1102DATS024h	0.36		1	0.5	
L06060563	1103DATS224h	1.80		1	<0.3	0.350
L06060564	1104DATS224h	1.80		1	0.3	
L06060565	1105DATS224h	1.80		1	0.4	
L06060566	1106DATS1024h	7.55		1	0.82	0.540
L06060567	1107DATS1024h	7.55		1	0.4	
L06060568	1108DATS1024h	7.55		1	0.4	

Test 9, Tissue Se Concentrations, Artemia

Raw Data	Submitter I.D.	Nominal Se ($\mu\text{g/L}$)	Exp Time (d)	Dry Wt $\mu\text{g/g}$	Mean $\mu\text{g/g}$	SD $\mu\text{g/g}$
LET I.D.	Submitter I.D.	($\mu\text{g/L}$)	(d)	Dry Wt	DryWt	DryWt
L06060428	1301AAATS00d	0.41	0	2.7	2.800	0.100
L06060429	1302AAATS00d	0.41	0	2.8		
L06060430	1303AAATS00d	0.41	0	2.9		
L06060431	1304AAATS01d	0.41	1	3.1	3.167	0.115
L06060432	1305AAATS01d	0.41	1	3.3		
L06060433	1306AAATS01d	0.41	1	3.1		
L06060440	1313AAATS02d	0.41	2	2.7	1.580	0.973
L06060441	1314AAATS02d	0.41	2	0.94		
L06060442	1315AAATS02d	0.41	2	1.1		
L06060453	1322AAATS04d	0.41	4	1.8	1.433	0.404
L06060454	1323AAATS04d	0.41	4	1		
L06060455	1324AAATS04d	0.41	4	1.5		
L06060462	1331AAATS010d	0.41	10	1.4	0.930	0.418
L06060463	1332AAATS010d	0.41	10	0.79		
L06060464	1333AAATS010d	0.41	10	0.6		
L06060434	1307AAATS1001d	8.17	1	3.2	3.067	0.115
L06060435	1308AAATS1001d	8.17	1	3		
L06060436	1309AAATS1001d	8.17	1	3		
L06060443	1316AAATS1002d	8.17	2	1.6	1.600	0.200
L06060444	1317AAATS1002d	8.17	2	1.8		
L06060445	1318AAATS1002d	8.17	2	1.4		
L06060456	1325AAATS1004d	8.17	4	1.8	2.000	0.200
L06060457	1326AAATS1004d	8.17	4	2		
L06060458	1327AAATS1004d	8.17	4	2.2		
L06060465	1334AAATS10010d	8.17	10	1.6	1.567	0.153
L06060466	1335AAATS10010d	8.17	10	1.4		
L06060467	1336AAATS10010d	8.17	10	1.7		
L06060437	1310AAATS10001d	206	1	4.1	4.000	0.100
L06060438	1311AAATS10001d	206	1	3.9		
L06060439	1312AAATS10001d	206	1	4		
L06060446	1319AAATS10002d	206	2	6.5	6.537	0.064
L06060447	1320AAATS10002d	206	2	6.5		
L06060452	1321AAATS10002d	206	2	6.61		
L06060459	1328AAATS10004d	206	4	6.09	6.133	0.746
L06060460	1329AAATS10004d	206	4	5.41		
L06060461	1330AAATS10004d	206	4	6.9		
L06060468	1337AAATS100010d	206	10	0.44	0.453	0.051
L06060469	1338AAATS100010d	206	10	0.51		
L06060470	1339AAATS100010d	206	10	0.41		

Test 10, Tissue Se Concentrations, Artemia

Raw Data		Nominal Se ($\mu\text{g/L}$)	Exp Time (d)	$\mu\text{g/g}$	Mean $\mu\text{g/g}$	SD $\mu\text{g/g}$
LET I.D.	Submitter I.D.			Dry Wt	DryWt	DryWt
L06060472	1400AATS00d	0.41	0	2.2	2.000	0.200
L06060478	1401AATS00d	0.41	0	2		
L06060479	1402AATS00d	0.41	0	1.8		
L06060480	1406AATS01d	0.41	1	2.2	2.333	0.115
L06060481	1407AATS01d	0.41	1	2.4		
L06060482	1408AATS01d	0.41	1	2.4		
L06060486	1412AATS02d	0.41	2	2.3	2.333	0.058
L06060487	1413AATS02d	0.41	2	2.3		
L06060488	1414AATS02d	0.41	2	2.4		
L06060492	1418AATS04d	0.41	4	1.3	0.993	0.272
L06060494	1419AATS04d	0.41	4	0.9		
L06060495	1420AATS04d	0.41	4	0.78		
L06060502	1424AATS010d	0.41	10	2.4	1.800	0.656
L06060503	1425AATS010d	0.41	10	1.9		
L06060504	1426AATS010d	0.41	10	1.1		
L06060483	1409AATS1001d	8.75	1	2.7	2.533	0.153
L06060484	1410AATS1001d	8.75	1	2.4		
L06060485	1411AATS1001d	8.75	1	2.5		
L06060489	1415AATS1002d	8.75	2	2.4	2.400	0.100
L06060490	1416AATS1002d	8.75	2	2.5		
L06060491	1417AATS1002d	8.75	2	2.3		
L06060496	1421AATS1004d	8.75	4	1.8	1.867	0.306
L06060497	1422AATS1004d	8.75	4	2.2		
L06060498	1423AATS1004d	8.75	4	1.6		
L06060505	1427AATS10010d	8.75	10	2	1.867	0.153
L06060506	1428AATS10010d	8.75	10	1.9		
L06060507	1429AATS10010d	8.75	10	1.7		

Test 11, Tissue Se Concentrations, Dunaliella

Raw Data		Actual Se ($\mu\text{g/L}$)	Exp Time (d)	$\mu\text{g/g}$	Mean $\mu\text{g/g}$	SD $\mu\text{g/g}$
LET I.D.	Submitter I.D.			Dry Wt	DryWt	DryWt
L06060365	1500DATS00d	0.51	0	0	0.000	0.000
L06060366	1501DATS00d	0.51	0	0		
L06060367	1502DATS00d	0.51	0	0		
L06060368	1503DATS04d	0.51	4	0	0.133	0.231
L06060369	1504DATS04d	0.51	4	0		
L06060370	1505DATS04d	0.51	4	0.4		
L06060380	1515DATS08d	0.51	8	0	0.167	0.153
L06060381	1516DATS08d	0.51	8	0.3		
L06060382	1517DATS08d	0.51	8	0.2		
L06060396	1527DATS012d	0.51	12	0	0.267	0.231
L06060397	1528DATS012d	0.51	12	0.4		
L06060398	1529DATS012d	0.51	12	0.4		
L06060371	1506DATS24d	2.75	4	reject	#DIV/0!	#DIV/0!
L06060372	1507DATS24d	2.75	4	reject		
L06060373	1508DATS24d	2.75	4	reject		
L06060383	1518DATS28d	2.75	8	2	1.000	1.000
L06060384	1519DATS28d	2.75	8	1		
L06060389	1520DATS28d	2.75	8	0		
L06060399	1530DATS212d	2.75	12	2	1.867	0.231
L06060400	1531DATS212d	2.75	12	1.6		
L06060401	1532DATS212d	2.75	12	2		
L06060374	1509DATS104d	12.2	4	1	1.033	0.058
L06060375	1510DATS104d	12.2	4	1.1		
L06060376	1511DATS104d	12.2	4	1		
L06060390	1521DATS108d	12.2	8	1	1.067	0.058
L06060391	1522DATS108d	12.2	8	1.1		
L06060392	1523DATS108d	12.2	8	1.1		
L06060402	1533DATS1012d	12.2	12	2	2.067	0.058
L06060403	1534DATS1012d	12.2	12	2.1		
L06060404	1535DATS1012d	12.2	12	2.1		
L06060377	1512DATS274d	33.35	4	0	#DIV/0!	#DIV/0!
L06060378	1513DATS274d	33.35	4	0		reject, low mass
L06060379	1514DATS274d	33.35	4	8		reject, low mass
L06060393	1524DATS1278d	33.35	8	2	2.400	0.693
L06060394	1525DATS1278d	33.35	8	3.2		
L06060395	1526DATS1278d	33.35	8	2		
L06060405	1536DATS2712d	33.35	12	3.2	3.200	0.200
L06060406	1537DATS2712d	33.35	12	3		
L06060407	1538DATS2712d	33.35	12	3.4		

Data from Algal Cultures, SeO ₃		Data from Algal Cultures				
Raw Data		Actual Se (µg/L)	Exp Time (d)	µg/g Dry Wt	Mean µg/g DryWt	SD µg/g DryWt
LET I.D.	Submitter I.D.					
L06060413	C1DATS012d	0.51	12	0.8	0.400	0.566
L06060414	C2DATS012d	0.51	12	0		
L06060419	C9DATS020d	0.51	20	0	0.200	0.283
L06060420	C10DATS020d	0.51	20	0.4		
L06060415	C3DATS212d	2.75	12	2.3	2.350	0.071
L06060416	C4DATS212d	2.75	12	2.4		
L06060421	C11DATS220d	2.75	20	2.2	2.200	0.000
L06060422	C12DATS220d	2.75	20	2.2		
L06060417	C5DATS1012d	12.2	12	2.5	2.500	0.000
L06060418	C6DATS1012d	12.2	12	2.5		
L06060423	C13DATS1020d	12.2	20	2.4	2.200	0.283
L06060424	C14DATS1020d	12.2	20	2		

Test 12, Tissue Se Concentrations, Artemia, Aqueous Exposure

Raw Data		Actual Se ($\mu\text{g/L}$)	Exp Time (d)	$\mu\text{g/g}$ Dry Wt	Mean $\mu\text{g/g}$	SD $\mu\text{g/g}$
LET I.D.	Submitter I.D.			DryWt		DryWt
L06060509	1600AATS00	0.41	0	2.2	2.433	0.208
L06060510	1601AATS00	0.41	0	2.5		
L06060511	1602AATS00	0.41	0	2.6		
L06060512	1603AATS01d	0.41	1	1.8	1.500	0.300
L06060513	1604AATS01d	0.41	1	1.2		
L06060514	1605AATS01d	0.41	1	1.5		
L06060521	1615AATS02d	0.41	2	2.7	2.700	0.000
L06060522	1616AATS02d	0.41	2	2.7		
L06060526	1617AATS02d	0.41	2	2.7		
L06060533	1627AATS04d	0.41	4	2.6	2.467	0.115
L06060534	1628AATS04d	0.41	4	2.4		
L06060535	1629AATS04d	0.41	4	2.4		
L06060542	1639AATS010d	0.41	10	1.4	1.270	0.411
L06060543	1640AATS010d	0.41	10	1.6		
L06060544	1641AATS010d	0.41	10	0.81		
L06060515	1606AATS21d	2.41	1	1.3	1.333	0.153
L06060516	1607AATS21d	2.41	1	1.2		
L06060517	1608AATS21d	2.41	1	1.5		
L06060527	1618AATS22d	2.41	2	2.5	2.600	0.100
L06060528	1619AATS22d	2.41	2	2.7		
L06060529	1620AATS22d	2.41	2	2.6		
L06060536	1630AATS24d	2.41	4	2.8	2.733	0.058
L06060537	1631AATS24d	2.41	4	2.7		
L06060538	1632AATS24d	2.41	4	2.7		
L06060545	1642AATS210d	2.41	10	1.3	1.367	0.058
L06060550	1643AATS210d	2.41	10	1.4		
L06060551	1644AATS210d	2.41	10	1.4		
L06060518	1609AATS101d	11.61	1	1.2	1.267	0.208
L06060519	1610AATS101d	11.61	1	1.5		
L06060520	1611AATS101d	11.61	1	1.1		
L06060530	1621AATS102d	11.61	2	2.8	2.667	0.153
L06060531	1622AATS102d	11.61	2	2.7		
L06060532	1623AATS102d	11.61	2	2.5		
L06060539	1633AATS104d	11.61	4	2.6	2.633	0.058
L06060540	1634AATS104d	11.61	4	2.6		
L06060541	1635AATS104d	11.61	4	2.7		
L06060552	1645AATS1010d	11.61	10	1.8	1.567	0.252
L06060553	1646AATS1010d	11.61	10	1.6		
L06060554	1647AATS1010d	11.61	10	1.3		

Test 13, Tissue Se Concentrations, Artemia, Dietary and Aqueous Exposure

Raw Data		Actual	Exp Time	µg/g Dry Wt	Mean µg/g	SD µg/g
LET I.D.	Submitter I.D.	Se (µg/L)	(d)	Dry Wt	Dry Wt	Dry Wt
L06070328	1700ADTS00	0.42	0	2.3	2.500	0.173
L06070329	1701ADTS00	0.42	0	2.6		
L06070330	1702ADTS00	0.42	0	2.6		
L06070331	1703ADTS01d	0.42	1	2.9	2.800	0.100
L06070332	1704ADTS01d	0.42	1	2.7		
L06070333	1705ADTS01d	0.42	1	2.8		
L06070341	1715ADTS02d	0.42	2	2.8	2.633	0.379
L06070342	1716ADTS02d	0.42	2	2.9		
L06070343	1717ADTS02d	0.42	2	2.2		
L06070353	1727ADTS04d	0.42	4	2.4	2.467	0.115
L06070354	1728ADTS04d	0.42	4	2.6		
L06070355	1729ADTS04d	0.42	4	2.4		
L06070362	1739ADTS010d	0.42	10	2.6	2.467	0.153
L06070363	1740ADTS010d	0.42	10	2.3		
L06070364	1741ADTS010d	0.42	10	2.5		
L06070334	1706ADTS21d	2.54	1	2.7	2.667	0.058
L06070335	1707ADTS21d	2.54	1	2.7		
L06070337	1708ADTS21d	2.54	1	2.6		
L06070344	1718ADTS22d	2.54	2	2.6	2.733	0.153
L06070345	1719ADTS22d	2.54	2	2.7		
L06070346	1720ADTS22d	2.54	2	2.9		
L06070356	1730ADTS24d	2.54	4	2.6	2.633	0.058
L06070357	1731ADTS24d	2.54	4	2.7		
L06070358	1732ADTS24d	2.54	4	2.6		
L06070365	1742ADTS210d	2.54	10	2	2.367	0.635
L06070366	1743ADTS210d	2.54	10	2		
L06070367	1744ADTS210d	2.54	10	3.1		
L06070338	1709ADTS101d	10.65	1	2.8	2.767	0.058
L06070339	1710ADTS101d	10.65	1	2.7		
L06070340	1711ADTS101d	10.65	1	2.8		
L06070347	1721ADTS102d	10.65	2	2.8	2.733	0.208
L06070348	1722ADTS102d	10.65	2	2.9		
L06070351	1723ADTS102d	10.65	2	2.5		
L06070359	1733ADTS104d	10.65	4	2.5	2.667	0.153
L06070360	1734ADTS104d	10.65	4	2.7		
L06070361	1735ADTS104d	10.65	4	2.8		
L06070368	1745ADTS1010d	10.65	10	4.1	3.050	1.485
L06070369	1746ADTS1010d	10.65	10	<3		
L06070370	1747ADTS1010d	10.65	10	2		

APPENDIX D

**Tables 6.D. Averaged Tissue Accumulation of Selenium, Presented in Order of Tests
(also presented above in text)**

Test 1, Dunaliella SeO ₄				
Observed SeO ₄ ($\mu\text{g L}^{-1}$)	Nominal Se ($\mu\text{g L}^{-1}$)	Exp Time (d)	Mean Se ($\mu\text{g g}^{-1}$ dwt)	SD Se ($\mu\text{g g}^{-1}$ dwt)
0.0	0.0	0	0.00	0.00
0.4	0.5	0	0.00	0.00
0.4	0.5	1	0.00	0.00
0.4	0.5	2	0.00	0.00
0.4	0.5	4	0.00	0.00
9.3	9	0	0.01	0.006
9.3	9	0.17	0.01	0.009
9.3	9	1	0.01	0.003
9.3	9	2	0.01	0.007
9.3	9	4	0.01	0.008
16.6	18	0	0.001	0.001
16.6	18	0.17	0.000	0.001
16.6	18	1	0.001	0.001
16.6	18	2	0.003	0.003
16.6	18	4	0.007	0.002
23.5	27	0	0.005	0.007
23.5	27	0.17	0.014	0.013
23.5	27	1	0.015	0.013
23.5	27	2	0.039	0.008
23.5	27	4	0.022	0.008
44.5	54	0	0.001	0.002
44.5	54	0.17	0.000	0.000
44.5	54	1	0.000	0.000
44.5	54	2	0.020	0.006
44.5	54	4	0.068	0.007

Test 2, Artemia, Aqueous SeO ₄				
Observed SeO ₄ ($\mu\text{g L}^{-1}$)	Nominal Se ($\mu\text{g L}^{-1}$)	Exp Time (d)	Mean Se ($\mu\text{g g}^{-1}$ dwt)	SD Se ($\mu\text{g g}^{-1}$ dwt)
0.4	0.5	0	0.14	0.06
0.4	0.5	1	0.08	0.04
0.4	0.5	4	0.10	0.01
23.1	27	0	0.18	0.07
23.1	27	1	0.10	0.00
23.1	27	4	0.09	0.01
44.5	54	0	0.16	0.07
44.5	54	1	0.11	0.06
44.5	54	4	0.09	0.02

Tests 3 & 4, Artemia, Aqueous SeO ₄				
Observed SeO ₄ ($\mu\text{g L}^{-1}$)	Nominal Se ($\mu\text{g L}^{-1}$)	Exp Time (d)	Mean Se ($\mu\text{g g}^{-1}$ dwt)	SD Se ($\mu\text{g g}^{-1}$ dwt)
0.4	0.5	0	0.27	0.11
0.4	0.5	0.17	0.27	0.04
0.4	0.5	2	0.18	0.07
0.4	0.5	6	2.73	1.27
0.4	0.5	8	1.67	0.40
0.4	0.5	10	1.10	0.00*
23.1	27	0.17	0.41	0.06
23.1	27	2	0.20	0.06
23.1	27	6	2.93	0.61
23.1	27	8	2.37	0.46
23.1	27	10	2.50	1.56
44.5	54	0.17	0.50	0.08
44.5	54	2	0.19	0.03
44.5	54	6	3.10	0.26
44.5	54	8	2.40	0.20
44.5	54	10	1.77	0.35
84.0	108	1	3.83	1.07
84.0	108	4	4.50	3.13

*, only one sample for this conc and time period, rejected other 2 reps for low tissue mass

Test 5, Dunaliella SeO ₄					
Observed SeO ₄ ($\mu\text{g L}^{-1}$)	Nominal Se ($\mu\text{g L}^{-1}$)	SO ₄ ²⁻ (mg L^{-1})	Exp Time (d)	Mean Se ($\mu\text{g g}^{-1}$ dwt)	SD Se ($\mu\text{g g}^{-1}$ dwt)
2.4	2	2.5	4	0.00	0.00
2.4	2	2.5	8	0.00	0.00
2.4	2	2.5	12	0.00	0.00
2.4	2	2.5	20	0.00	0.00
8.6	10	2.5	4	0.08	0.01
8.6	10	2.5	8	0.03	0.05
8.6	10	2.5	12	0.00	0.00
8.6	10	2.5	20	0.00	0.00
8.6	10	25	4	0.03	0.06
8.6	10	25	8	0.03	0.06
8.6	10	25	12	0.17	0.06
8.6	10	25	20	0.00	0.00
0.0	0.5	8000	0	0.00	0.00
0.0	0.5	8000	4	0.02	0.04
0.0	0.5	8000	8	0.02	0.03
0.0	0.5	8000	12	0.13	0.15
0.0	0.5	8000	20	0.18	0.16
2.4	2	8000	4	0.00	0.00
2.4	2	8000	8	0.07	0.00
2.4	2	8000	12	0.00	0.00
2.4	2	8000	20	0.00	0.00
8.6	10	8000	4	0.03	0.04
8.6	10	8000	8	0.09	0.02
8.6	10	8000	12	0.05	0.07
8.6	10	8000	20	0.22	0.02

Test 6, Dunaliella SeO ₄				
Observed SeO ₄ ($\mu\text{g L}^{-1}$)	Nominal Se ($\mu\text{g L}^{-1}$)	Exp Time (d)	Mean Se ($\mu\text{g g}^{-1}$ dwt)	SD Se ($\mu\text{g g}^{-1}$ dwt)
0.7	0.5	45	0.95	0.32
0.7	0.5	60	1.04	0.08
1.7	2	45	0.85	0.22
1.7	2	60	0.83	0.23
7.6	10	45	1.08	0.40
7.6	10	60	1.40	0.42
21.0	27	45	1.43	0.31
21.0	27	60	1.75	0.07

Test 7, Artemia, Dietary and Aqueous SeO ₄				
Observed SeO ₄ ($\mu\text{g L}^{-1}$)	Nominal Se ($\mu\text{g L}^{-1}$)	Exp Time (d)	Mean Se ($\mu\text{g g}^{-1}$ dwt)	SD Se ($\mu\text{g g}^{-1}$ dwt)
0.4	0.5	0	0.910	0.046
0.4	0.5	0.17	2.900	0.100
0.4	0.5	0.5	1.267	0.351
0.4	0.5	1	1.867	0.981
0.4	0.5	2	3.233	0.153
0.4	0.5	4	2.300	0.624
0.4	0.5	8	1.550	0.778
0.4	0.5	20	3.533	0.306
0.4	0.5	40	4.133	0.764
2.0	2	0.17	2.100	0.794
2.0	2	0.5	1.550	0.071
2.0	2	1	1.333	0.153
2.0	2	2	3.167	0.115
2.0	2	4	1.600	0.400
2.0	2	8	0.893	0.179
2.0	2	20	4.000	0.346
2.0	2	40	3.150	1.061
9.1	10	0.17	3.000	0.000
9.1	10	0.5	1.067	0.252
9.1	10	1	1.700	0.265
9.1	10	2	3.167	0.231
9.1	10	4	2.633	0.115
9.1	10	8	2.800	0.707
9.1	10	20	4.267	0.115
9.1	10	40	3.650	0.495
27.1	27	0.17	3.133	0.153
27.1	27	0.5	1.533	0.252
27.1	27	1	1.433	0.321
27.1	27	2	3.200	0.100
27.1	27	4	2.967	0.153
27.1	27	8	1.500	0.707
27.1	27	20	3.967	0.306
27.1	27	40	4.267	0.681

Test 8, Dunaliella, Matrix Change in Se in 24-h					
Observed Se _{O₄} ($\mu\text{g L}^{-1}$)	Nominal Se ($\mu\text{g L}^{-1}$)	Exp Time (d)	Se ($\mu\text{g g}^{-1}$ dwt)	Mean Se ($\mu\text{g g}^{-1}$ dwt)	SD Se ($\mu\text{g g}^{-1}$ dwt)
			0.2	0.457	0.238
0.7	0.5	1	0.67		
0.0	0.5	1	0.5		
			<0.3	0.350	0.071
1.7	2	1	0.3		
1.9	2	1	0.4		
			0.82	0.540	0.242
7.5	10	1	0.4		
7.6	10	1	0.4		

Test 9, Artemia, Aqueous SeO ₄					
Observed Se _{O₄} ($\mu\text{g L}^{-1}$)	Nominal Se ($\mu\text{g L}^{-1}$)	Exp Time (d)	Mean Se ($\mu\text{g g}^{-1}$ dwt)	SD Se ($\mu\text{g g}^{-1}$ dwt)	
0.4	0.5	0	2.800	0.100	
0.4	0.5	1	3.167	0.115	
0.4	0.5	2	1.580	0.973	
0.4	0.5	4	1.433	0.404	
0.4	0.5	10	0.930	0.418	
8.2	10	1	3.067	0.115	
8.2	10	2	1.600	0.200	
8.2	10	4	2.000	0.200	
8.2	10	10	1.567	0.153	
206	200	1	4.000	0.100	
206	200	2	6.537	0.064	
206	200	4	6.133	0.746	
206	200	10	10.000	1.130	
Initial Se for 206 ppb 10 d			0.453	0.051	

Masses from LET appear incorrect for 3 reps of 200 ppb Se by factor of 22.45

Test 10, Artemia, Aqueous Unfiltered SeO ₄ , Bacterial Role				
Observed SeO ₄ ($\mu\text{g L}^{-1}$)	Nominal Se ($\mu\text{g L}^{-1}$)	Exp Time (d)	Mean Se ($\mu\text{g g}^{-1}$ dwt)	SD Se ($\mu\text{g g}^{-1}$ dwt)
0.4	0.5	0	2.000	0.200
0.4	0.5	1	2.333	0.115
0.4	0.5	2	2.333	0.058
0.4	0.5	4	0.993	0.272
0.4	0.5	10	1.800	0.656
8.8	10	1	2.533	0.153
8.8	10	2	2.400	0.100
8.8	10	4	1.867	0.306
8.8	10	10	1.867	0.153

Identical results of 1.87 are correct, just coincidence

Test 11, Dunaliella SeO ₃ , Laboratory Experiment				
Observed SeO ₃ ($\mu\text{g L}^{-1}$)	Nominal Se ($\mu\text{g L}^{-1}$)	Exp Time (d)	Mean Se ($\mu\text{g g}^{-1}$ dwt)	SD Se ($\mu\text{g g}^{-1}$ dwt)
0.5	0.5	0	0.000	0.000
0.5	0.5	4	0.133	0.231
0.5	0.5	8	0.167	0.153
0.5	0.5	12	0.267	0.231
2.8	2	4	*	
2.8	2	8	1.000	1.000
2.8	2	12	1.867	0.231
12.2	10	4	1.033	0.058
12.2	10	8	1.067	0.058
12.2	10	12	2.067	0.058
33.4	27	4	*	
33.4	27	8	2.400	0.693
33.4	27	12	3.200	0.200

*Reject, masses low & values $>8 \mu\text{g g}^{-1}$

Dunaliella Culture SeO ₃ , Concurrently Analyzed with Test 11				
Observed SeO ₃ ($\mu\text{g L}^{-1}$)	Nominal Se ($\mu\text{g L}^{-1}$)	Exp Time (d)	Mean Se ($\mu\text{g g}^{-1}$ dwt)	SD Se ($\mu\text{g g}^{-1}$ dwt)
0.5	0.5	0	0.000	0.000
0.5	0.5	12	0.400	0.566
0.5	0.5	20	0.200	0.283
2.8	2	12	2.350	0.071
2.8	10	20	2.200	0.000
12.2	2	12	2.500	0.000
12.2	10	20	2.200	0.283

Test 12, Artemia, Aqueous Uptake SeO ₃				
Observed SeO ₃ ($\mu\text{g L}^{-1}$)	Nominal Se ($\mu\text{g L}^{-1}$)	Exp Time (d)	Mean Se ($\mu\text{g g}^{-1}$ dwt)	SD Se ($\mu\text{g g}^{-1}$ dwt)
0.41	0.5	0	2.433	0.208
0.41	0.5	1	1.500	0.300
0.41	0.5	2	2.700	0.000
0.41	0.5	4	2.467	0.115
0.41	0.5	10	1.270	0.411
2.41	2	1	1.333	0.153
2.41	2	2	2.600	0.100
2.41	2	4	2.733	0.058
2.41	2	10	1.367	0.058
11.61	10	1	1.267	0.208
11.61	10	2	2.667	0.153
11.61	10	4	2.633	0.058
11.61	10	10	1.567	0.252

Test 13, Artemia, Dietary and Aqueous SeO ₃				
Observed SeO ₃ ($\mu\text{g L}^{-1}$)	Nominal Se ($\mu\text{g L}^{-1}$)	Exp Time (d)	Mean Se ($\mu\text{g g}^{-1}$ dwt)	SD Se ($\mu\text{g g}^{-1}$ dwt)
0.4	0.5	0	2.500	0.173
0.4	0.5	1	2.800	0.100
0.4	0.5	2	2.633	0.379
0.4	0.5	4	2.467	0.115
0.4	0.5	10	2.467	0.153
2.5	2	1	2.667	0.058
2.5	2	2	2.733	0.153
2.5	2	4	2.633	0.058
2.5	2	10	2.367	0.635
10.6	10	1	2.767	0.058
10.6	10	2	2.733	0.208
10.6	10	4	2.667	0.153
10.6	10	10	3.050	1.485

APPENDIX E

Tables 6.E. Aqueous Selenium: Raw Data From Individual Replicates in All Tests

Lab	Test #	Lab ID	Submitter ID	Test Method	Det. Lim. (ug/L)	Expect Se (ug/L)	Observed Se (ug/L)	Mean Se (ug/L)	SD	CV	Diff From Expected
											Na
KUCC	1	AN16723	UW9/05-DVA-SE0-0-1/3	hydride	2	0	< 2	BDL	na	na	-500%
		AN16724	UW9/05-DVA-SE0-0-2/3	hydride	2	0	< 2				
		AN16725	UW9/05-DVA-SE0-0-3/3	hydride	2	0	< 2				
		AN16726	UW9/05-DVA-SE1-0-1/3	hydride	2	0.5	< 2	3.00	1.41	47%	
		AN16727	UW9/05-DVA-SE1-0-2/3	hydride	2	0.5	2				
		AN16728	UW9/05-DVA-SE1-0-3/3	hydride	2	0.5	4				
		AN16729	UW9/05-DVA-SE9-0-1/2	hydride	2	9	11	10.00	1.41	14%	
		AN16730	UW9/05-DVA-SE9-0-2/2	hydride	2	9	9				
		AN16731	UW9/05-DVA-SE18-0-1/2	hydride	2	18	24	17.50	9.19	53%	
		AN16732	UW9/05-DVA-SE18-0-2/2	hydride	2	18	11				
		AN16733	UW9/05-DVA-SE27-0-1/2	hydride	2	27	20	19.50	0.71	4%	
		AN16734	UW9/05-DVA-SE27-0-2/2	hydride	2	27	19				
		AN16735	UW9/05-DVA-SE54-0-1/2	hydride	2	54	35	40.50	7.78	19%	
		AN16736	UW9/05-DVA-SE54-0-2/2	hydride	2	54	46				
		AN16737	UW9/05-DVA-SE9-24-1/2-F	hydride	2	9	10	10.00	0.00	0%	
		AN16738	UW9/05-DVA-SE9-24-2/2-F	hydride	2	9	10				
		AN16739	UW9/05-DVA-SE18-24-1/2-F	hydride	2	18	14	14.00	0.00	0%	
		AN16740	UW9/05-DVA-SE18-24-2/2-F	hydride	2	18	14				
		AN16741	UW9/05-DVA-SE27-24-1/2-F	hydride	2	27	35	26.00	12.73	49%	
		AN16742	UW9/05-DVA-SE27-24-2/2-F	hydride	2	27	17				
		AN16743	UW9/05-DVA-SE54-24-1/2-F	hydride	2	54	40	43.00	4.24	10%	
		AN16744	UW9/05-DVA-SE54-24-2/2-F	hydride	2	54	46				
		AN16745	UW9/05-DVA-SE9-48-1/2-F	hydride	2	9	12	12.00	0.00	0%	
		AN16746	UW9/05-DVA-SE9-48-2,2-F	hydride	2	9	12				
		AN16747	UW9/05-DVA-SE18-48-1/2-F	hydride	2	18	16	15.00	1.41	9%	
		AN16748	UW9/05-DVA-SE18-48-2/2-F	hydride	2	18	14				
		AN16749	UW9/05-DVA-SE27-48-1/2-F	hydride	2	27	22	24.00	2.83	12%	
		AN16750	UW9/05-DVA-SE27-48-2/2-F	hydride	2	27	26				
		AN16751	UW9/05-DVA-SE54-48-1/2-F	hydride	2	54	46	48.50	3.54	7%	
		AN16752	UW9/05-DVA-SE54-48-2/2-F	hydride	2	54	51				
		AN16753	UW9/05-DVA-SE9-96-1/2-F	hydride	2	9	9	9.50	0.71	7%	
		AN16754	UW9/05-DVA-SE9-96-2/2-F	hydride	2	9	10				
		AN16755	UW9/05-DVA-SE18-96-1/2-F	hydride	2	18	17	20.00	4.24	21%	

Lab	Test #	Lab ID	Submitter ID	Test Method	Det. Lim. (ug/L)	Expect Se (ug/L)	Observed Se (ug/L)	Mean Se (ug/L)	SD	CV	Diff From Expected
AN	16756	AN16756	UW9/05-DVA-SE18-96-2/2-F	hydride	2	18	23				
		AN16757	UW9/05-DVA-SE27-96-1/2-F	hydride	2	27	26	24.50	2.12	9%	9%
		AN16758	UW9/05-DVA-SE27-96-2/2-F	hydride	2	27	23				
		AN16759	UW9/05-DVA-SE54-96-1/2-F	hydride	2	54	55	55.00	0.00	0%	-2%
		AN16760	UW9/05-DVA-SE54-96-2/2-F	hydride	2	54	55				
LET	1	L05090177	UW 9/05-DVA-SE54-0-2/2rep	hydride	0.5	54	44	na	na	na	19%
		L05090178	UW 9/05-DVA-SE27-24-2/2Fr	hydride	0.5	27	12	na	na	na	56%
		L05090179	UW 9/05-DVA-SE18-48-2/2Fr	hydride	0.5	18	14	na	na	na	22%
		L05090180	UW 9/05-DVA-SE9-96-2/2Fr	hydride	0.5	9	8.5	na	na	na	6%
		L05090182	UW 9/05-DVA-SE54-96-1/2Fr	hydride	0.5	54	44	na	na	na	19%
KUCC	2	AN18209	UW 10-05 AFAA-SE1-0-1-2A	hydride	2	0.5	0.5	0.40	0.17	43%	20%
		AN18210	UW 10-05 AFAA-SE1-0-2-2A	hydride	2	0.5	21	Average of reasonable values			
		AN18211	UW 10-05 AFAA-SE1-0-1-2B	hydride	2	0.5	0.5				
		AN18212	UW 10-05 AFAA-SE1-0-2-2B	hydride	2	0.5	0.2	15.01	10.01	67%	-2902%
		AN18213	UW 10-05 AFAA-SE1-4-1-2F	hydride	2	0.5	4.9				
		AN18214	UW 10-05 AFAA-SE1-4-2-2F	hydride	2	0.5	< 2				
		AN18215	UW 10-05 AFAA-SE1-24-1-2I	hydride	2	0.5	< 2				
		AN18216	UW 10-05 AFAA-SE1-24-2-2I	hydride	2	0.5	< 2				
		AN18217	UW 10-05 AFAA-SE1-24-1-2F	hydride	2	0.5	26				
		AN18218	UW 10-05 AFAA-SE1-24-2-2F	hydride	2	0.5	25				
		AN18219	UW 10-05 AFAA-SE1-48-1-2F	hydride	2	0.5	23				
		AN18220	UW 10-05 AFAA-SE1-48-2-2F	hydride	2	0.5	26				
		AN18221	UW 10-05 AFAA-SE1-96-1-2I	hydride	2	0.5	18				
		AN18222	UW 10-05 AFAA-SE1-96-2-2I	hydride	2	0.5	17				
		AN18223	UW 10-05 AFAA-SE1-96-1-2F	hydride	2	0.5	17				
		AN18224	UW 10-05 AFAA-SE1-96-2-2F	hydride	2	0.5	16				
		AN18225	UW 10-05 AFAA-SE27-0-1-2	hydride	2	27	22	23.07	7.82	34%	15%
		AN18226	UW 10-05 AFAA-SE27-0-2-2	hydride	2	27	19				
		AN18227	UW 10-05 AFAA-SE27-4-1-2	hydride	2	27	17				
		AN18228	UW 10-05 AFAA-SE27-4-2-2	hydride	2	27	16				
		AN18229	UW 10-05 AFAA-SE27-24-1-2I	hydride	2	27	16				
		AN18230	UW 10-05 AFAA-SE27-24-2-2I	hydride	2	27	15				

Lab	Test #	Lab ID	Submitter ID	Test Method	Det. Lim. (ug/L)	Expect Se (ug/L)	Observed Se (ug/L)	Mean Se (ug/L)	SD	CV	Diff From Expected
		AN18231	UW 10-05 AFAA-SE27-24-1-2F	hydride	2	27	44				
		AN18232	UW 10-05 AFAA-SE27-24-2-2F	hydride	2	27	32				
		AN18233	UW 10-05 AFAA-SE27-48-1-2F	hydride	2	27	21				
		AN18234	UW 10-05 AFAA-SE27-48-2-2F	hydride	2	27	20				
		AN18235	UW 10-05 AFAA-SE27-96-1-2I	hydride	2	27	26				
		AN18236	UW 10-05 AFAA-SE27-96-2-2I	hydride	2	27	21				
		AN18237	UW 10-05 AFAA-SE27-96-1-2F	hydride	2	27	27				
		AN18238	UW 10-05 AFAA-SE27-96-2-2F	hydride	2	27	27				
		AN18239	UW 10-05 AFAA-SE54-0-1-2	hydride	2	54	22	44.50	16.85	38%	18%
		AN18240	UW 10-05 AFAA-SE54-0-2-2	hydride	2	54	20				
		AN18241	UW 10-05 AFAA-SE54-4-1-2	hydride	2	54	15				
		AN18242	UW 10-05 AFAA-SE54-4-2-2	hydride	2	54	17				
		AN18243	UW 10-05 AFAA-SE54-24-1-2I	hydride	2	54	17				
		AN18244	UW 10-05 AFAA-SE54-24-2-2I	hydride	2	54	5				
		AN18245	UW 10-05 AFAA-SE54-24-1-2F	hydride	2	54	40				
		AN18246	UW 10-05 AFAA-SE54-24-2-2F	hydride	2	54	47				
		AN18247	UW 10-05 AFAA-SE54-48-1-2	hydride	2	54	47				
		AN18248	UW 10-05 AFAA-SE54-48-2-2	hydride	2	54	44				
		AN18249	UW 10-05 AFAA-SE54-96-1-2I	hydride	2	54	3				
		AN18250	UW 10-05 AFAA-SE54-96-2-2I	hydride	2	54	5				
		AN18251	UW 10-05 AFAA-SE54-96-1-2F	hydride	2	54	4				
		AN18252	UW 10-05 AFAA-SE54-96-2-2F	hydride	2	54	5				
KUCC	3	AN20829	118AAS16D	hydride	2	0.5	4	5.00	1.10	22%	-900%
		AN20830	119AAS16D	hydride	2	0.5	4				
		AN20831	120AAS18D	hydride	2	0.5	5				
		AN20832	121AAS18D	hydride	2	0.5	5				
		AN20833	122AAS110D	hydride	2	0.5	5				
		AN20834	123AAS110D	hydride	2	0.5	7				
		AN20835	142AAS276D	hydride	2	27	24	23.83	0.41	2%	12%
		AN20836	143AAS276D	hydride	2	27	24				
		AN20837	145AAS278D	hydride	2	27	23				
		AN20838	146AAS278D	hydride	2	27	24				
		AN20839	147AAS2710D	hydride	2	27	24				

Lab	Test #	Lab ID	Submitter ID	Test Method	Det. Lim. (ug/L)	Expect Se (ug/L)	Observed Se (ug/L)	Mean Se (ug/L)	SD	CV	Diff From Expected
AN		AN20840	148AAS2710D	hydride	2	27	24				
		AN20841	167AAS546D	hydride	2	54	47	48.17	2.40	5%	11%
		AN20842	168AAS546D	hydride	2	54	50				
		AN20843	169AAS548D	hydride	2	54	44				
		AN20844	170AAS548D	hydride	2	54	48				
		AN20845	171AAS5410D	hydride	2	54	50				
		AN20846	172AAS5410D	hydride	2	54	50				
LET	3	L05100224	144 AAS 276r	hydride	0.5	27	16	na	na	na	41%
		L05100226	173 AAS 548dr	hydride	0.5	54	31	na	na	na	43%
		L05100228	184 AAS 10896-r	hydride	0.5	108	63.2	na	na	na	41%
KUCC	4	AN20847	181AAS10824	hydride	2	108	78	84.00	7.12	8%	22%
		AN20848	182AAS10824	hydride	2	108	78				
		AN20849	183AAS10896	hydride	2	108	92				
		AN20850	184AAS10896	hydride	2	108	88				
KUCC	5 & 6	AO00791	677DAS048	hydride	2	0.5	6	5.50	0.71	13%	-1000%
		AO00792	678DAS048	hydride	2	0.5	5				
		AO00793	679DAS248	hydride	2	2	3	3.00	0.00	0%	-50%
		AO00794	680DAS248	hydride	2	2	3				
		AO00795	681DAS1048	hydride	2	10	7	8.00	1.41	18%	20%
		AO00796	682DAS1048R	hydride	2	10	9				
		AO00797	684DAS242.5	hydride	2	2	3	2.50	0.71	28%	-25%
		AO00798	685DAS242.5	hydride	2	2	2				
		AO00799	687DAS1042.5	hydride	2	10	7	7.50	0.71	9%	25%
		AO00800	688DAS1042.5	hydride	2	10	8				
		AO00801	689DAS10425	hydride	2	10	14	13.50	0.71	5%	-35%
		AO00802	690DAS10425	hydride	2	10	13				
		AO00803	691DAS088	hydride	2	0.5	4	4.00	0.00	0%	-700%
		AO00804	692DAS088	hydride	2	0.5	4				
		AO00805	694DAS288	hydride	2	2	6	6.00	0.00	0%	-200%
		AO00806	695DAS288	hydride	2	2	6				

Lab	Test #	Lab ID	Submitter ID	Test Method	Det. Lim. (ug/L)	Expect Se (ug/L)	Observed Se (ug/L)	Mean (ug/L)	Se	SD	CV	Diff From Expected
		AO00807	696DAS1088	hydride	2	10	14	15.00	1.41	9%	-50%	
		AO00808	697DAS1088	hydride	2	10	16					
		AO00809	698DAS282.5	hydride	2	2	4	4.00	0.00	0%	-100%	
		AO00810	699DAS282.5	hydride	2	2	4					
		AO00811	700DAS1082.5	hydride	2	10	13	10.50	3.54	34%	-5%	
		AO00812	702DAS1082.5	hydride	2	10	8					
		AO00813	703DAS10825	hydride	2	10	14	14.00	0.00	0%	-40%	
		AO00814	704DAS10825	hydride	2	10	14					
		AO00815	719DAS0208	hydride	2	0.5	5	3.50	2.12	61%	-600%	
		AO00816	720DAS0208	hydride	2	0.5	2					
		AO00817	721DAS2208	hydride	2	2	3	3.50	0.71	20%	-75%	
		AO00818	722DAS10208	hydride	2	2	4					
		AO00819	724DAS10208	hydride	2	10	10	10.50	0.71	7%	-5%	
		AO00820	725DAS10208	hydride	2	10	11					
		AO00821	726DAS2202.5	hydride	2	2	0.9	0.70	0.28	40%	65%	
		AO00822	727DAS2202.5	hydride	2	2	0.5					
		AO00823	728DAS10202.5	hydride	2	10	8	8.75	0.96	11%	13%	
		AO00824	729DAS10202.5	hydride	2	10	8					
		AO00825	730DAS102025	hydride	2	10	10					
		AO00826	731DAS102025R	hydride	2	10	9					
LET	5 & 6	L05120097	723DAS2208R	hydride	0.5	2	1.7	na	na	na	15%	
		L05120098	732DAS10202.5	hydride	0.5	10	6.8	na	na	na	32%	
		L05120099	693DAS088R	hydride	0.5	0.5	0	na	na	na	100%	
		L05120045	686DAS242.5R	hydride	0.5	2	1	na	na	na	50%	
		L05120047	706DAS0128R	hydride	0.5	0.5	0	na	na	na	100%	
		L05120049	716DAS10122.5R	hydride	0.5	10	4.2	na	na	na	58%	
KUCC	EQC	AO00827	734 SE 54	hydride	2	54	49	na	na	na	9%	
		AO00828	735 SE 0	hydride	2	0.5	0	na	na	na	100%	
		AO00829	736 SE 2	hydride	2	2	0	na	na	na	100%	
		AO00830	736 SE 10	hydride	2	10	5	na	na	na	50%	
		AO00831	738 SE 27	hydride	2	27	21	na	na	na	22%	

Lab	Test #	Lab ID	Submitter ID	Test Method	Det. Lim. (ug/L)	Expect Se (ug/L)	Observed Se (ug/L)	Mean Se (ug/L)	SD	CV	Diff From Expected
KUCC 7	AO00832	739 SE 54		hydride	2	54	45	na	na	na	17%
	AO06103	920ADAS00		ICP	2	0.5	2.6	2.7	0.1	5%	440%
	AO06104	921ADAS00		ICP	2	0.5	2.8				
	AO06105	922ADAS20		ICP	2	2.0	4.4	4.4	0	0%	120%
	AO06106	923ADAS20		ICP	2	2.0	4.4				
	AO06107	924ADAS100		ICP	2	10.0	11.0	11.2	0.2	2%	12%
	AO06108	925ADAS100		ICP	2	10.0	11.3				
	AO06109	927ADAS270		ICP	2	27.0	28.7	27.1	2.3	8%	0%
	AO06110	928ADAS270		ICP	2	27.0	25.5				
KUCC 8	AO09105	1110DAAS024HF		ICP	2	0.5	1.8	2.2	0.5	23%	330%
	AO09100	1111DAAS00HI		ICP	2	0.5	2.5				
	AO09106	1113DAAS024HF		ICP	2	0.5	2.1	3.9	2.5	64%	670%
	AO09101	1115DAAS20HI		ICP	2	2.0	5.6				
	AO09107	1116DAAS224HF		ICP	2	2.0	4.5	4.6	0.1	2%	128%
	AO09102	1117DAAS20HI		ICP	2	2.0	4.6				
	AO09115	1119DAAS224HF		ICP	2	2.0	2.7	8.3	7.9	95%	315%
	AO09103	1121DAAS100HI		ICP	2	10.0	13.9				
	AO09108	1122DAAS1024HF		ICP	2	10.0	9.9	12.8	4	32%	28%
	AO09104	1123DAAS100HI		ICP	2	10.0	15.6				
	AO09109	1125DAAS1024HF		ICP	2	10.0	10.4	5.5	7	128%	-46%
KUCC EQC	AO09110	1201HAS0		ICP	2	0.0	0.5				
	AO09111	1205HAS2		ICP	2	2.0	0.5	4.8	6	127%	138%
	AO09112	1209HAS10		ICP	2	10.0	9.0				
	AO09113	1211QCAS10		ICP	2	10.0	11.2	69.1	82	118%	591%
	AO09114	1213QCAS100		ICP	2	100.0	126.9				
KUCC 7	AO06103	920ADAS00		hydride	2	0.5	18.0	15.0	4.2	28%	2900%
	AO06104	921ADAS00		hydride	2	0.5	12.0				
	AO06105	922ADAS20		hydride	2	2.0	8.0	7.5	0.7	9%	275%
	AO06106	923ADAS20		hydride	2	2.0	7.0				
	AO06107	924ADAS100		hydride	2	10.0	11.0	12.5	2.1	17%	25%
	AO06108	925ADAS100		hydride	2	10.0	14.0				

Lab	Test #	Lab ID	Submitter ID	Det.		Expect Se (ug/L)	Observed Se (ug/L)	Mean Se (ug/L)	SD	CV	Diff From Expected
				Method	Lim. (ug/L)						
		AO06109	927ADAS270	hydride	2	27.0	8.0	8.5	0.7	8%	-69%
		AO06110	928ADAS270	hydride	2	27.0	9.0				
KUCC	8	AO09105	1110DAAS024HF	hydride	2	0.5	3.0	4.5	2.1	47%	800%
		AO09100	1111DAAS00HI	hydride	2	0.5	6.0				
		AO09106	1113DAAS024HF	hydride	2	0.5	3.0	3.5	0.7	20%	600%
		AO09101	1115DAAS20HI	hydride	2	2.0	4.0				
		AO09107	1116DAAS224HF	hydride	2	2.0	4.0	4.0	0	0%	100%
		AO09102	1117DAAS20HI	hydride	2	2.0	4.0				
		AO09115	1119DAAS224HF	hydride	2	2.0	4.0	4.0	0	0%	100%
		AO09103	1121DAAS100HI	hydride	2	10.0	4.0				
		AO09108	1122DAAS1024HF	hydride	2	10.0	6.0	5.0	1.4	28%	-50%
		AO09104	1123DAAS100HI	hydride	2	10.0	4.0				
		AO09109	1125DAAS1024HF	hydride	2	10.0	10.0	4.2	4	96%	-58%
LET	8	L06050309	1112DAAS00h1R	hydride	0.5	0.5	0.7	na	na	na	40%
		L06050310	1118DAAS20h1R	hydride	0.5	2	1.7	na	na	na	-15%
		L06050311	1124DAAS100h1R	hydride	0.5	10	7.5	na	na	na	-25%
		L06050312	1114DAAS024hFR	hydride	0.5	0	BDL	na	na	na	Na
		L06050313	1120DAAS224hFR	hydride	0.5	2	1.9	na	na	na	-5%
		L06050314	1126DAAS1024hFR	hydride	0.5	10	7.6	na	na	na	-24%
KUCC	EQC	AO09110	1201HAS0	hydride	2	0.0	0.0	na	na	na	na
		AO09111	1205HAS2	hydride	2	2.0	3.0	na	na	na	50%
		AO09112	1209HAS10	hydride	2	10.0	9.0	na	na	na	-10%
		AO09113	1211QCAS10	hydride	2	10.0	11.0	na	na	na	10%
		AO09114	1213QCAS100	hydride	2	100.0	85.0	na	na	na	-15%
LET	EQC	L06050315	1200HAS0	hydride	0.5	0	0	na	na	na	na
		L06050316	1204HAS2	hydride	0.5	2	2.3	na	na	na	15%
		L06050317	1208HAS10	hydride	0.5	10	10	na	na	na	0%
		L06050318	1210QCAS10	hydride	0.5	10	9.7	na	na	na	-3%
		L06050319	1212QCAS100	hydride	0.5	100	94	na	na	na	-6%

Lab	Test #	Lab ID	Submitter ID	Test Method	Det. Lim. (ug/L)	Expect Se (ug/L)	Observed Se (ug/L)	Mean (ug/L)	Se	SD	CV	Diff From Expected
BR	8	06BR1088-01	1127DAAS00	hydride	0.4	0.5	0.41	0.41		0.00	0%	-18%
		06BR1088-02	1128DAAS00R	hydride	0.4	0.5	0.41					
		06BR1088-03	1129DAAS20	hydride	0.4	2	0.41	0.41		0.00	0%	-80%
		06BR1088-04	1130DAAS20R	hydride	0.4	2	0.41					
		06BR1088-05	1131DAAS100	hydride	0.4	10	0.89	0.84		0.07	842%	-92%
		06BR1088-06	1132DAAS100R	hydride	0.4	10	0.79					
BR	9	06BR1088-07	1373AAAS00	hydride	0.4	0.5	0.41	0.41		0.00	0%	-18%
		06BR1088-08	1374AAAS00R	hydride	0.4	0.5	0.41					
		06BR1088-09	1375AAAS1000	hydride	0.4	10	8.26	8.17		0.13	2%	-18%
		06BR1088-10	1376AAAS1000R	hydride	0.4	10	8.07					
		06BR1088-11	1377AAAS10000	hydride	0.4	200	205	206.00		1.41	1%	3%
		06BR1088-12	1378AAAS10000R	hydride	0.4	200	207					
BR	10	06BR1088-13	1452AAAS00	hydride	0.4	0.5	0.41	0.41		0.00	0%	-18%
		06BR1088-14	1453AAAS00R	hydride	0.4	0.5	0.41					
		06BR1088-15	1454AAAS1000	hydride	0.4	10	9.18	8.75		0.61	7%	-13%
		06BR1088-16	1455AAAS1000R	hydride	0.4	10	8.32					
BR	11	06BR1088-17	1586DAAS013d	hydride	0.4	0.5	0.67	0.51		0.14	28%	1%
		06BR1088-18	1590DAAS019d	hydride	0.4	0.5	0.41					
		06BR1088-19	1594DAAS020d	hydride	0.4	0.5	0.44					
		06BR1088-20	1587DAAS213d	hydride	0.4	2	2.82	2.75		0.44	16%	37%
		06BR1088-21	1591DAAS219d	hydride	0.4	2	3.15					
		06BR1088-22	1595DAAS220d	hydride	0.4	2	2.27					
		06BR1088-23	1588DAAS1013d	hydride	0.4	10	12.8	12.20		0.56	5%	22%
		06BR1088-24	1592DAAS1019d	hydride	0.4	10	12.1					
		06BR1088-25	1596DAAS1020d	hydride	0.4	10	11.7					
		06BR1088-26	1589DAAS2713d	hydride	0.4	27	32.8	25.83		13.03	50%	-4%
		06BR1088-27	1593DAAS2719d	hydride	0.4	27	10.8					
		06BR1088-28	1597DAAS2720d	hydride	0.4	27	33.9					
BR	12	06BR1088-29	1651AAAS00	hydride	0.4	0.5	0.41	0.41		0.00	0%	-18%

Lab	Test #	Lab ID	Submitter ID	Test Method	Det. Lim. (ug/L)	Expect Se (ug/L)	Observed Se (ug/L)	Mean Se (ug/L)	SD	CV	Diff From Expected
BR	13	06BR1088-30	1660AAAS09d	hydride	0.4	0.5	0.41				
		06BR1088-31	1686AAAS010d	hydride	0.4	0.5	0.41				
		06BR1088-32	1653AAAS20	hydride	0.4	2	3.01	2.41	0.67	28%	21%
		06BR1088-33	1662AAAS29d	hydride	0.4	2	2.53				
		06BR1088-34	1689AAAS210d	hydride	0.4	2	1.69				
		06BR1088-35	1655AAAS100	hydride	0.4	10	12.2	11.61	2.54	22%	16%
	13	06BR1088-36	1664AAAS109d	hydride	0.4	10	13.8				
		06BR1088-37	1691AAAS1010d	hydride	0.4	10	8.82				
BR	EQC	06BR1088-38	1751ADAS00	hydride	0.4	0.5	0.41	0.42	0.02	5%	-16%
		06BR1088-39	1755ADAS04d	hydride	0.4	0.5	0.41				
		06BR1088-40	1759ADAS09d	hydride	0.4	0.5	0.45				
		06BR1088-41	1763ADAS010d	hydride	0.4	0.5	0.41				
		06BR1088-42	1752ADAS20	hydride	0.4	2	2.69	2.54	0.22	9%	27%
		06BR1088-43	1756ADAS24d	hydride	0.4	2	2.71				
		06BR1088-44	1760ADAS29d	hydride	0.4	2	2.23				
		06BR1088-45	1764ADAS210d	hydride	0.4	2	2.52				
		06BR1088-46	1753ADAS100	hydride	0.4	10	10.1	10.65	0.71	7%	6%
		06BR1088-47	1757ADAS104d	hydride	0.4	10	11.1				
		06BR1088-48	1761ADAS109d	hydride	0.4	10	11.4				
		06BR1088-49	1765ADAS1010d	hydride	0.4	10	9.99				

APPENDIX F
Example of Variation Between Laboratories in Aqueous Selenium

Table 6.F. Comparison of Results from Kennecott Environmental Laboratory (KUCC) and Laboratory Environmental Testing (LET).

Submitter ID	KUCC ID	LET ID	Det Limit ($\mu\text{g L}^{-1}$)		Observed Se ($\mu\text{g L}^{-1}$)		Diff from expect. (%)	
			KUCC	LET	Expected Se ($\mu\text{g L}^{-1}$)	KUCC	LET	KUCC
677DAS048	AO00791			2	0.5	6		-1100.00%
678DAS048	AO00792			2	0.5	5		-900.00%
679DAS248	AO00793			2	2	3		-50.00%
680DAS248	AO00794			2	2	3		-50.00%
681DAS1048	AO00795			2	10	7		30.00%
682DAS1048R	AO00796			2	10	9		10.00%
684DAS242.5	AO00797			2	2	3		-50.00%
685DAS242.5	AO00798			2	2	2		0.00%
687DAS1042.5	AO00799			2	10	7		30.00%
688DAS1042.5	AO00800			2	10	8		20.00%
689DAS10425	AO00801			2	10	14		-40.00%
690DAS10425	AO00802			2	10	13		-30.00%
691DAS088	AO00803			2	0.5	4		-700.00%
692DAS088	AO00804	L05120099	0.05	2	0.5	4	0	-700.00%
694DAS288	AO00805			2	2	6		-200.00%
695DAS288	AO00806			2	2	6		-200.00%
696DAS1088	AO00807			2	10	14		-40.00%
697DAS1088	AO00808			2	10	16		-60.00%
698DAS282.5	AO00809			2	2	4		-100.00%
699DAS282.5	AO00810			2	2	4		-100.00%
700DAS1082.5	AO00811			2	10	13		-30.00%
702DAS1082.5	AO00812			2	10	8		20.00%
703DAS10825	AO00813			2	10	14		-40.00%
704DAS10825	AO00814			2	10	14		-40.00%
719DAS0208	AO00815			2	0.5	5		-900.00%
720DAS0208	AO00816			2	0.5	2		-300.00%
721DAS2208	AO00817			2	2	3		-50.00%
722DAS10208	AO00818	L05120097	0.05	2	2	4	1.7	-100.00%
724DAS10208	AO00819			2	10	10		0.00%
725DAS10208	AO00820			2	10	11		-10.00%
726DAS2202.5	AO00821			2	2	0.9		55.00%
727DAS2202.5	AO00822			2	2	0.5		75.00%
728DAS10202.5	AO00823			2	10	8		20.00%
729DAS10202.5	AO00824			2	10	8		20.00%
730DAS102025	AO00825			2	10	10		0.00%
731DAS102025R	AO00826	L05120098	0.05	2	10	9	6.8	10.00%
								32.00%

APPENDIX G
Photographs of Experimental System

Fig. 6.G.1. Raceways for Artemia Rearing. Oval raceways with air-water-lifts providing aeration and creating current.

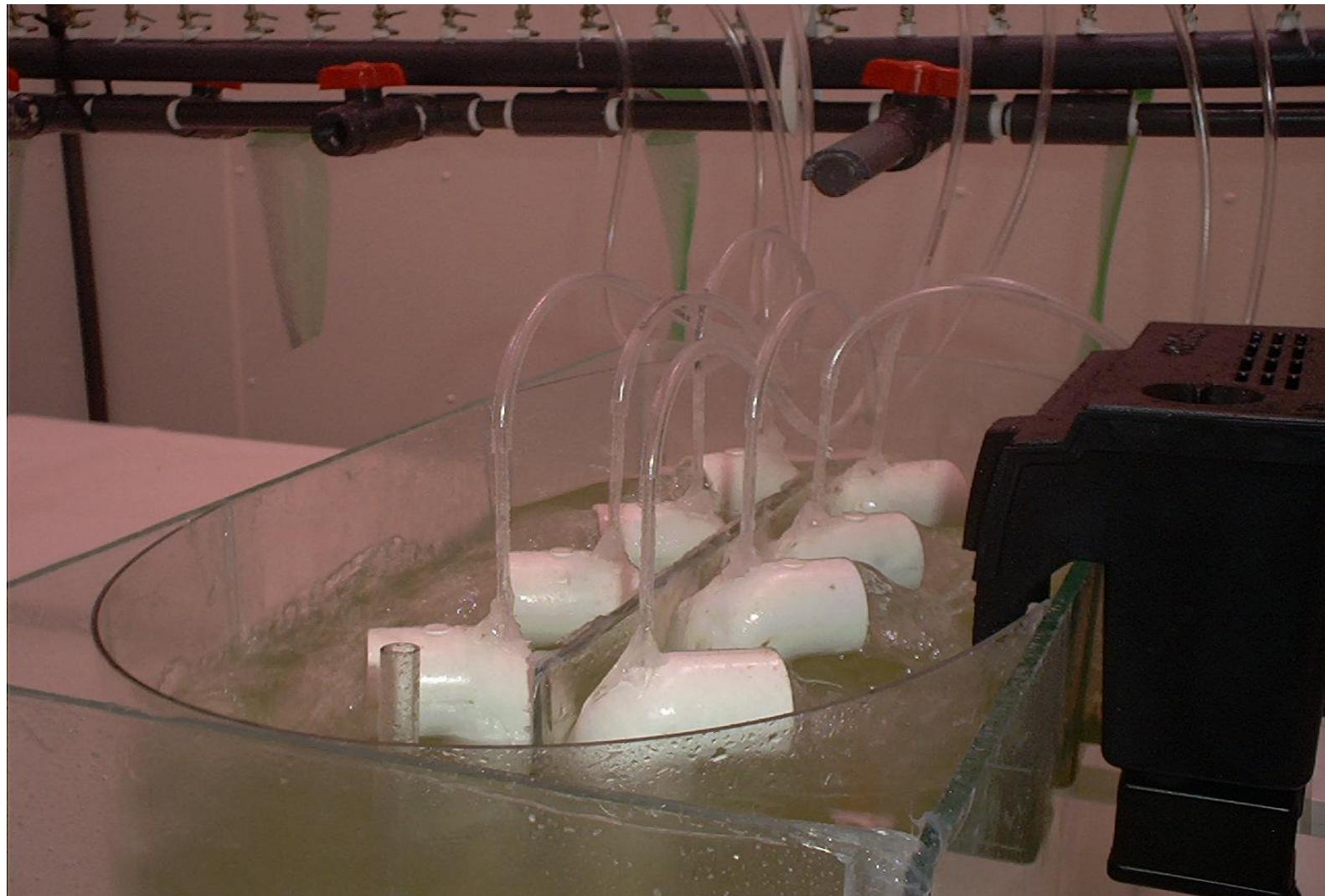


Fig. 6.F.2. Algal Culture System. Note lights mounted above, behind and on sides of culture tanks.



Fig. 6.G.3. Static-Renewal System with Recirculating Bath.



APPENDIX H

Table of Conditions for Test of Covaried Selenium and Salinity (Data Stored for Potential Future Analysis)

Table 6.G. Conditions for Test of Covaried Selenium and Salinity (Samples stored for future analysis)

Species	<i>Artemia franciscana</i>
Test start date	10-28-05
Exposure pathway	Aqueous
Se concentration ($\mu\text{g L}^{-1}$)¹	0, 9, 18, 27, 27, 54, 54, 108, 108
Salinities (g L^{-1}) associated with each Se concentration above	35, 120, 90, 15, 60, 15, 30, 15, 120
Exposure durations (d)²	0, 1, 2, 10
Exposure waters³	Great Salt Lake (1.0 um filtered)
Analytical intervals for aqueous Se	Test start, daily
Se species	Sodium selenate, Na_2SeO_4
Analytical intervals for Ph, salinity, O_2, and temperature	Test start, daily
Test objective	Effect of salinity on Se uptake

7. DATA ON DISK IN PDF FORM

A. Test Notes and Monitoring Observations with Corresponding Sample Codes and Conditions

B. Analytical Request Sheets and Selenium Reports